

Quality Assurance Project Plan And Sampling & Analysis Plan

**Route 113 Release Site
Limestone Township,
Kankakee County, Illinois**

*Antea Group Project No. PK09KAN3
March 24, 2014*

Prepared for:
Wood River Pipe Lines LLC
Five TEK Park
9999 Hamilton Boulevard
Breinigsville, PA 18031

Prepared by:
Antea[®] Group
5910 Rice Creek Parkway
Suite 100
Shoreview, MN 55126

Title: Route 113 Release QAPP/SAP

Revision Number: 1

Revision Date: 03/24/2014

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Group A – Title and Approval Sheets

A1 – Title Sheet

Quality Assurance Project Plan and Sampling & Analysis Plan for the Route 113 Release
Document Title

United States Environmental Protection Agency/Illinois Environmental Protection Agency
Lead Organizations

Richard Anderson, Antea Group (on behalf of Wood River Pipe Lines LLC)
Preparer's Name and Organizational Affiliation

5910 Rice Creek Parkway, Suite 100, Shoreview, MN 55126; 651-6975228;
richard.anderson@anteagroup.com
Preparer's Address, Telephone Number and E-mail Address

March 19, 2014
Preparation Date

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A1 – Approval Sheet

Approved by:

Mr. Jeffrey Brudereck Wood River Pipe Lines LLC – Senior Project Manager, Remediation (610) 904-4019 jbrudereck@buckeye.com	Date
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Mr. Andrew Maguire United States Environmental Protection Agency (USEPA) - On-Scene Coordinator (312) 353-8782 maguire.andrew@epa.gov	Date
--	------

Mr. Mark Retzlaff Illinois Environmental Protection Agency (IEPA) mark.retzlaff@illinois.gov	Date
--	------

Mr. Kendall Rannaoja Antea Group – Senior Project Manager (630)689-1102 kendall.rannaoja@anteagroup.com	Date
--	------

Mr. Neal Cleghorn First Environmental Laboratories, Inc. - Project Manager (630)778-1200 neal@firstenv.com	Date
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Ms. Kang Khang Pace Analytical Services Inc. - Project Manager 920-321-9407 Kang.Khang@pacelabs.com	Date
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Revision Date: March 24, 2014

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Ms. Kate Grams
Pace Analytical Services Inc. - Quality Assurance Manager
920-321-9426
Kate.Grams@pacelabs.com

Date

Ms. Lorrie Walker
First Environmental Laboratories, Inc. – Quality Assurance Manager
(630)778-1200
lorrie@firstenv.com

Date

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A3 – Distribution List

Ms. Katherine Zeth Wood River Pipe Lines LLC – Remediation Manager (610) 904-4494 kzeth@buckeye.com	Mr. Jeffrey Brudereck Wood River Pipe Lines LLC – Senior Remediation Project Manager (610) 904-4019 jbrudereck@buckeye.com
Mr. Andrew Maguire USEPA - On-Scene Coordinator (312) 353-8782 maguire.andrew@epa.gov	Mr. Kendall Rannaoja Antea Group – Senior Project Manager (630)689-1102 kendall.rannaoja@anteagroup.com
Mr. Mark Retzlaff IEPA – Environmental Protection Specialist (847)294-4070 mark.retzlaff@illinois.gov	Mr. Neal Cleghorn First Environmental Laboratories, Inc. - Project Manager (630)778-1200 neal@firstenv.com
Ms. Lorrie Walker First Environmental Laboratories, Inc. – Quality Assurance Manager (630)778-1200 lorrie@firstenv.com	Ms. Kang Khang Pace Analytical Services Inc. - Project Manager 920-321-9407 Kang.Khang@pacelabs.com
Ms. Kate Grams Pace Analytical Services Inc. - Quality Assurance Manager 920-321-9426 Kate.Grams@pacelabs.com	

A4 – Project/Task Organization

A4.1 Overview

The United States Environmental Protection Agency (USEPA) has overall responsibility for environmental affairs related to the Wood River Pipe Line Company LLC (Wood River) Route 113 Release site. Wood River has retained Antea Group as the lead contractor for the site investigation activities. Mr. Andrew Maguire, the USEPA On-Scene Coordinator, is responsible for oversight of project activities. An organizational chart for the project is included at the end of this section.

A4.2 Antea Group Personnel and Responsibilities

Antea Group is responsible for the work plan design, field investigation activities, coordination of subcontractors (driller and analytical laboratories), data review, and reporting. Antea Group's project team consists of a Senior Project Manager, Project Quality Assurance Officer, Project Professionals, Staff Professionals, CADD Specialists, Database Specialists, and a Geographic Information Systems (GIS) Specialist. Antea Group receives review and authorization of project tasks by the USEPA and Wood River.

Project Managers

The Antea Group project managers Mr. Kendall Rannaoja (primary) and Mr. Gary Schroeder are responsible for the management of this project. The project manager must oversee operations and ensure that all legal requirements are met. It is the project manager's duty to keep the project on schedule, within budget and to communicate regularly with the USEPA and Wood River regarding progress toward the specific goals. The project manager will work closely with the USEPA and Wood River to assure that objectives are met and all aspects of the work are proceeding in a mutually agreeable manner. The project manager will also be responsible for confirming that all project activities adhere to the work plan and this Quality Assurance Project Plan and Sampling and Analysis Plan (QAPP/SAP).

Project Quality Assurance Officer

Ms. Amy Wrigley will serve as the Project Quality Assurance Officer. Ms. Wrigley is responsible for specifying Quality Assurance/Quality Control (QA/QC) procedures, specifying field sampling and laboratory analysis methods to be utilized in the investigation, auditing the field and laboratory activities to ensure proper methods and procedures are followed, reviewing results and QC data and recommending changes to the procedures, if necessary. Ms. Wrigley will maintain the official, approved QAPP/SAP. Ms. Wrigley reports to Antea Group project managers.

Project and Staff Professionals

The Project and Staff Professionals will be responsible for field oversight of the surface water sampling, soil boring activities, potable well sampling, well drilling and installation and groundwater monitoring activities. The Project and Staff Professionals will be responsible for preparation (or updating) of the Site Health and Safety Plan, interpreting data, and results of the investigation and providing recommendations for actions at the site. The Project and Staff Professionals will also be responsible for the preparation of technical reports and assisting the project manager with project coordination. The Project and Staff Professionals report to Antea Group Project Managers.

CADD Specialist

The CADD specialist (drafter) will be responsible for the preparation of site drawings, maps and figures. The drafter will be experienced with CAD and other related computer equipment sufficient to perform computations required for completing the work.

GIS Specialist

The GIS specialist will be responsible for the coordination of Geographic Information Systems data, GIS data interpretation, and preparation of specialized maps and figures. The GIS specialist will report to Antea Group Project Managers and coordinate work with the CADD Specialist and Project/Staff Professionals.

Database Specialist

The Database specialist will be responsible for maintaining the analytical and sampling results database. The database specialist oversees the uploading of data into the database, functionality of the database, and database output. The database specialist works in coordination with all Antea Group personnel and the analytical laboratories. The database specialist reports to Antea Group Project Managers.

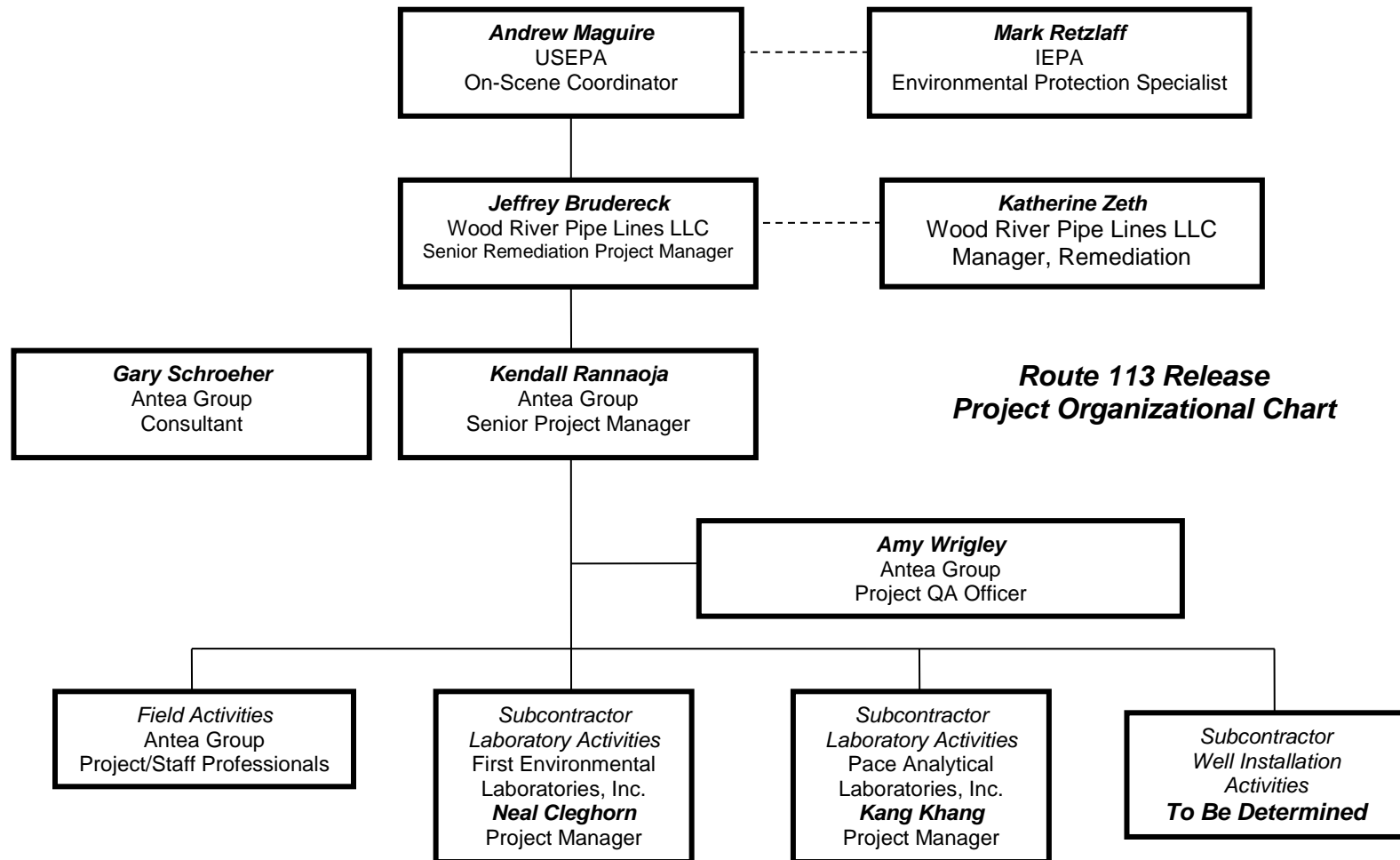
A4.3 Subcontractor Responsibilities

First Environmental Laboratories, Inc. (First) of Naperville, Illinois (Illinois Certification #: 100292), will be responsible for all initial response and soil and water sample analyses. Mr. Neal Cleghorn will be responsible for project management for the laboratory, and Ms. Lorrie Walker is First's Quality Assurance Manager. First will follow Standard Operating Procedures (SOP) detailed in their Quality Assurance Manual (QAM), which is on file at First.

Pace Analytical Services, Inc. (Pace) of Minneapolis, Minnesota, Green Bay, Wisconsin (Illinois Certification #: 200050), Indianapolis, Indiana (Illinois Certification #: 200074), and Lenexa, Kansas (Illinois Certification #: 200030), will be responsible for soil and water sample analyses that cannot be accommodated by First. Ms. Kang Khang (Green Bay) will be responsible for project management for the

laboratory, and Ms. Kate Grams is Pace's (Green Bay) Quality Assurance Manager. Pace will follow Standard Operating Procedures (SOP) detailed in their QAM, which is on file with Antea Group.

The well installation contractor will be responsible for the soil boring and monitoring well installation field activities. Antea Group will coordinate the work with the contractor and will assure that the drilling methods utilized during the investigation comply with those in this QAPP/SAP and the Site Health and Safety Plan.



A5 – Problem Definition and Background

A5.1 Problem Definition

The site investigation and monitoring activities include soil sampling (excavation and soil borings), monitoring well installation, groundwater sampling, and surface water sampling for the purposes of evaluating refined petroleum impacts in the area of the Route 113 Release site (Site) located near the intersection Illinois State Route 113 and Indian Trail in Limestone Township, Kankakee County, Illinois.

The soil and water contaminant concentration data will be evaluated against the Illinois Environmental Protection Agency (IEPA) Tiered Approach to Corrective Action Objectives (TACO) (**Appendix A**).

Investigation results will define the extent of the petroleum hydrocarbon impacts, and a report will be prepared that will include general recommendations for corrective actions. If the petroleum hydrocarbon impacts extend beyond the sampling locations in this investigation, a report will be prepared which includes recommendations for additional investigation.

A5.2 Background

A5.2.1 Site Location

The Illinois Route 113 Release site is located along Illinois State Route 113 in Limestone Township, Kankakee County, Illinois (Figure 1 and Figure 2). Investigation activities described herein will take place along Illinois Route 113 and in the affected areas both north and south of the road.

A5.2.2 Site History

The site originates at the pipe line release point, where refined petroleum has been observed on the ground surface to the north of the road and along surface drainage pathways within 500 feet of the road. Subsurface impacts have been observed on the north and south sides of Illinois Route 113 during exposure of the pipelines for future repair activities.

Data used in the development of the groundwater, surface water, and soil boring monitoring program for this site was based on the results of the emergency response recovery activities designed to recover the refined petroleum that was released. Response, recovery, and pipeline repair efforts are currently in progress.

A5.2.3 Site Geology and Hydrogeology

Geological information from the vicinity of the site indicates that surficial deposits typically consist of surficial soils consisting of clayey silt to a depth of two (2) to five (5) feet below ground surface (bgs). The uppermost bedrock unit underlying the surficial units in the area of the site consist of limestone and

dolomite. The bedrock occurs at a depth of approximately two (2) to five (5) feet bgs in the vicinity of the site. Depth to groundwater is anticipated to be at six (6) to ten (10) feet bgs. The vertical gradient of the groundwater is expected to be upward. Regional groundwater flow is generally north toward the Kankakee River.

A6 – Project/Task Description

Task 1 – Sampling Activities – Area 1

For Area (1), following excavation of impacted soil during repair of the 162 Line and 163 Line, the sidewalls and bottom of the excavation will be field screened with a photoionization detector (PID) to determine if additional petroleum-impacted soil needs to be removed. Once field screening indicates that sufficient impacted soil has been removed, post-excavation soil samples will be collected from the sidewalls and excavation bottom per the TACO Regulations in 35 Illinois Administrative Code. Sidewalls samples will be collected directly above the excavation bottom approximate 20 foot intervals along each sidewall, with a minimum of one per sidewall. In addition, samples will be collected from the excavation bottom, unless this is not possible due to the presence of competent bedrock, in an approximate grid on 20 foot centers. Soil samples will be collected directly from the excavator bucket or utilizing decontaminated hand tools after excavation activities have been completed. Following receipt and evaluation of Area (1) soil post excavation sample results, the need for additional delineation soil borings or soil excavation will be determined.

Soil samples collected from Area (1) will be analyzed for volatile organic compounds (VOCs) via USEPA Method 8260, Polynuclear Aromatic Hydrocarbons (PNAs) via USEPA Method 8270, and Total Petroleum Hydrocarbons (TPH) Gasoline Range Organics (GRO) and Diesel Range Organics (DRO) via USEPA Method 8015 per TACO Regulations. Soil samples will be analyzed by First Environmental Laboratories, Inc., in Naperville, IL or Pace Analytical Services, Inc. in Green Bay, WI.

Task 2 – Sampling Activities – Area 2

In Area (2), an 'interceptor trench' was installed (in a roughly east-west direction) for the collection of product and impacted water via vac truck, approximately 40 feet north of Illinois Route 113, in the Wood River Right-of-Way (ROW). On March 17, 2014, an area of surficial soil that exhibited sheen was excavated from this interceptor trench to the north. The excavation was approximately 13 feet in width at the southern extent, and 48 feet at its widest at the northern extent, and approximately 6-8 inches in depth. Post-excavation soil samples of these areas will be collected at a later date. Post-excavation samples will be collected per TACO Regulations in 35 Illinois Administrative Code.

An additional 'interceptor trench' was installed approximately 600 feet north of Illinois Route 113, in the Wood River ROW, to expose the 162 Line and 163 Lines and make observations regarding potential impacts or product migration. Due to the absence of visual impact to the surface water and soil in the trench, it was backfilled. Prior to backfilling, two soil samples were collected from the trench location to be sent for laboratory analysis of the analytes listed below.

Soil borings will be installed to the east, north, and west of these areas until un-impacted soil is encountered in each direction (Figure 3). A soil sample will be collected from the vertical interval exhibiting the highest field screening reading with a PID from each soil boring location, in order to determine the relative area of soil impacts and provide horizontal delineation. In the event that a positive PID reading is not observed, a soil sample will be collected from the interval of 0 to six (6) inches below the surface vegetation layer. Following repair of the pipeline, and following the collection of all product and impacted water which can feasibly be collected, any additional petroleum-impacted soil in this area will be excavated, using the soil borings as a relative guide. The need for additional soil sampling to the south of Illinois Route 113 and/or below the road way will be determined based on the results of the initial round of soil borings in this area.

Soil samples collected from Area (2) will be analyzed for VOCs via USEPA Method 8260, PNAs via USEPA Method 8270, and TPH GRO and DRO via USEPA Method 8015 per TACO Regulations. Soil samples will be analyzed with First Environmental Laboratories, Inc., in Naperville, IL or Pace Analytical Services, Inc. in Green Bay, WI.

Task 3 - Soil Boring and Well Installation

Additional soil borings may be advanced to characterize the impacts remaining. These soil borings will be utilized to define the extent of impact from the petroleum release. Additional soil borings will be proposed if the impacts are not horizontally delineated by the initial soil borings as described in Task 2. Soil samples collected from the soil borings will be submitted for laboratory analysis of VOCs via USEPA Method 8260, PNAs via USEPA Method 8270, and TPH GRO and DRO via USEPA Method 8015 per TACO Regulations. Soil samples will be analyzed with First Environmental Laboratories, Inc., in Naperville, IL or Pace Analytical Services, Inc. in Green Bay, WI.

Soil borings may be advanced into the bedrock utilizing sonic drilling techniques and converted into monitoring wells. The monitoring well locations are chosen based on the need for "source" area wells, "downgradient" area wells, and "upgradient" area wells, appropriateness for calculation of groundwater flow direction, as well as site access constraints. Additional monitoring wells may be proposed, if necessary, after review of the data collected from the initial monitoring wells. The depth to bedrock is

estimated at approximately one (1) to five (5) feet below grade. Groundwater is anticipated to be encountered at approximately six (6) to ten (10) feet below grade. Actual well depths will be dependent on field conditions; Antea Group field personnel will work closely with the well drillers to assure the wells are constructed such that the wells are screened at a depth where there is sufficient water.

Continuous sampling will be conducted during advancement of the borings to confirm lithology and the location of the groundwater table, and to allow for proper monitoring well screen placement. The monitoring wells will be constructed within the soil borings and completed above-grade. The wells will be constructed and developed in accordance with 77 Illinois Administrative Code 920.170.

The shallow groundwater monitoring wells will be utilized to define the extent of any shallow groundwater impacts that may be present. Installation of additional wells, including nested deep wells, will be considered based on field observations or after review of the groundwater sampling results and slug testing of these initial monitoring wells.

Task 4 - Groundwater Sampling

Following installation and development, groundwater samples will be collected from any newly installed monitoring wells. Groundwater samples collected from the monitoring wells will be submitted for laboratory analysis of VOCs via USEPA Method 8260 and PNAs via USEPA Method 8270 per TACO Regulations. Additionally, field parameters will be collected from each well (temperature, conductivity, pH, dissolved oxygen), and slug tests will be performed on two of the monitoring wells in order to determine hydraulic conductivity.

Additional monitoring well installation locations will be determined based on the initial monitoring well results. All results will be included in the site investigation report, along with boring log and well completion reports for each well.

In addition, a door-to-door receptor survey and fact sheet distribution to inform local property owners of the petroleum release is underway. If requested and/or approved by property owners, existing potable groundwater wells are being sampled. Groundwater samples collected from the potable wells are being submitted for laboratory analysis of VOCs by USEP Method 524.2 and PNAs by USEPA Method 625. Results will be reported to the property owners and included in the site investigation report.

Task 5 –Surface Water Sampling

Surface water sampling has been conducted at the locations on Figure 4. Surface water has been collected at these locations and analyzed for VOCs and PNAs. Surface water sample locations are

located around the release area and along a surface water flow path in order to monitor the release along the flow path.

The current sampling schedule is biweekly sampling for VOCs and PNAs in the surface water.

Task 6 - Receptor Survey

Antea Group identified potable water well receptors within ½-mile of the release as presented in Figure 5. Antea Group will prepare a complete receptor survey which will follow IEPA guidelines, and receptor survey data will be included in the site investigation report. A release information fact sheet is being distributed to local property owners and groundwater samples have been collected from area potable wells as approved by the property owners. Additional rounds of potable well sampling are currently being conducted.

Task 7 - Data Analysis and Reporting

All field data forms and laboratory analytical reports will be organized in a site investigation report and submitted to the appropriate Agencies. The site investigation report will include:

- A summary of Antea Group's site activities;
- Data compilation and tabulation of the laboratory reports from soil boring samples;
- Data compilation and tabulation of the laboratory reports from groundwater monitoring well samples;
- Data compilation and tabulation of the laboratory reports from surface water samples;
- Data compilation and tabulation from soil waste profiling sampling laboratory reports;
- Updated site maps and figures identifying the location of the soil borings, monitoring wells, and surface water sampling locations, and figures outlining the area & extent of impacts to each media;
- Updated well receptor survey data and figures;
- Contractor well logs and documentation; and,
- Recommendations for additional assessment and/or corrective action, as warranted.

Task 8 – Backfill Soil Sampling

Excavated soil will be replaced with clean backfill. Clean backfill will consist of soils with concentrations of hazardous substances or contaminants below residential or background soil screening levels as determined by IEPA. Samples collected from potential backfill source areas will be composite samples analyzed for Target Compounds List included in 35 IAC 740.

Schedule

Fieldwork is currently anticipated to occur throughout 2014. Any additional investigation activities beyond the current scope of work described herein would be covered with a separate QAPP/SAP.

Activity	Anticipated Date of Initiation	Anticipated Date of Completion
Excavation and sampling	March 2014	April 2014
Soil borings	March 2014	April 2014
Surface water sampling	Biweekly	May 2014
Residential Well Sampling	Biweekly	June 2014
Monitoring well installation and sampling	March 2014	TBD
Site investigation and monitoring report	TBD	TBD

Routine monitoring of surface water and groundwater has been ongoing since the petroleum release occurred. The table below details the current sampling schedule for each media. When analytical results indicate that all concentrations are below laboratory detection limits on a regular basis, a request will be made to reduce the sampling frequency.

Sampling Schedule	Current Sampling Frequency	Proposed Future Sampling Frequency
Surface Water Sampling	Biweekly	Monthly/Quarterly
Residential Sampling	Biweekly	Weekly/Monthly
Groundwater Sampling	N/A	Monthly/Quarterly

A7 – Quality Objectives and Criteria

A7.1 Data Quality Objectives

Overview

The data quality objective (DQO) process is detailed in the USEPA document *Guidance for the Data Quality Objectives Process* (EPA/240/B-06/001, February 2006). The USEPA defines the DQO process as a seven-step systematic planning approach utilized during data evaluation to support decision making when selecting between two or more clearly defined alternatives. The process steps are as follows:

- State the Problem
- Identify the Goal of the Study
- Identify Information Inputs
- Define the Boundaries of the Study
- Develop the Analytical Approach
- Specify Performance or Acceptance Criteria
- Develop the Plan for Obtaining Data

The final product of the DQO process is a plan for collecting data that includes limits on the probabilities of making decision errors. The process steps are addressed throughout this QAPP. A discussion will be included in the final report that will assess and document precision, accuracy and completeness of the data collected as part of this study, and how these parameters affect the usability of the data collected per the requirements of the QAPP.

Project-Specific DQOs

The QA procedures described within this QAPP/SAP are the result of continual evaluation of project goals utilizing the DQO process by Antea Group and the USEPA.

A7.2 Quality Assurance Objectives

Overview

QA objectives are formulated for the scope of work to maintain the precision, accuracy, completeness and representativeness of all data-generating activities. These activities include field investigations, sampling and laboratory analyses. The purpose of the QA objectives is summarized below:

<u>Activity</u>	<u>General Tasks</u>	<u>Purpose of QA Objectives</u>
Drilling and Monitoring Well Installation	-Direct-push drilling -Sonic drilling	Maintain reliable and representative data through use of standardized drilling methods and procedures. Prevention of cross-contamination through proper decontamination procedures.
Field Measurements	-Groundwater elevation measurements -Multi-parameter collection -Slug testing	Control findings through calibration, field tests, maintenance, and comparison to known information.
Sampling	-Groundwater sampling -Soil sampling -Surface water sampling	Prevention of cross-contamination through the use of proper decontamination, sampling, and shipping procedures. Ensure collection of representative samples.
Laboratory	-Chemical analysis of samples	Maintain high data quality through approved methodologies, accuracy and precision protocols, comparability, and overall data completeness. Maintain reliable and representative data through use of standardized methods and procedures. Prevention of cross-contamination through proper decontamination procedures.

Precision, Accuracy, Completeness and Representativeness of Data

Standard data acquisition requirements will be utilized when applicable. The following sections summarize how those requirements will be applied, when appropriate. Antea Group will provide a review of the analytical data to verify that data quality objectives were met based on the requirements outlined in this QAPP/SAP. Table 2 describes the number and frequency of samples to be obtained for quality control purposes.

Precision

Precision is a measure of data variation when more than one measurement is taken on the same sample. The precision estimate for duplicate measurements can be expressed as the relative percent difference (RPD):

$$RPD = \frac{|C1 - C2|}{C} \times 100\%$$

where: C1 = concentration for duplicate #1

C2 = concentration for duplicate #2

c = mean concentration

Laboratory duplicate measurements will be obtained for each set of samples submitted and analyzed. Acceptable precision limits will have a RPD value of less than 25% for groundwater samples.

Accuracy

Accuracy is the agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations; a data quality indicator. Accuracy of laboratory analysis is assessed by measuring standard reference material and spiked samples as laboratory control samples. Standard reference materials are utilized to calibrate laboratory measurement instruments. Laboratory control samples and matrix spike samples are prepared by taking an aliquot of blank matrix or sample matrix and spiking the aliquot with a known quantity of a constituent of interest, and analyzing to determine the spike recovery. Spike recovery is expressed as percent recovery:

$$\text{Percent Recovery} = \frac{(SSR - SR)}{SA} \times 100\%$$

where: SSR = Spike Sample Result
SR = Sample Result
SA = Spike Added

Completeness

Completeness is an estimate of the amount of valid data obtained from the analytical measurement system for a given set of data. The percent completeness is defined as the number of samples analyzed that meet the data quality goals divided by the total number of samples analyzed multiplied by 100. The completeness goal for this project is 95%.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of an environmental condition. Comparability is an expression of the confidence with which one data set can be compared to another. The representativeness and comparability of a sample is controlled by the sample collection and handling methods.

Representativeness of specific samples will be evaluated through the collection and analysis of duplicate samples. Methods of sample collection and handling are designed to minimize sample contamination,

disturbance, or alteration prior to analysis by the laboratory. Detailed descriptions of sample collection methods are included in Section B2 of this plan.

A8 – Special Training/Certifications

A8.1 Training Records

Field measurements and sample collection will be conducted by Antea Group personnel experienced in soil, groundwater and surface water sampling techniques and data management, including the calibration and use of specific monitoring instrumentation and sampling equipment, and for collecting and submitting the sample media to the contracted laboratories for chemical analysis. Antea Group personnel and contracted field crews will follow their respective SOP and this QAPP/SAP for conducting all field activities. Antea Group personnel and contracted field crews will have a 40-hour hazardous waste training certification.

Antea Group's 40-hour Occupational Safety and Health Administration (OSHA) training records along with the documentation of any refresher training are maintained on a centralized computer database. All field personnel and field supervisors will have 40-hour OSHA training and any applicable refresher training. Ms. Susan Dake, Antea Group's Corporate Health, Safety, Security and Environment, is responsible for the centralized computer database and training programs.

The drilling contractor for this project is undetermined at this time. The contractor is responsible for maintaining 40-hour OSHA training records along with the documentation of any refresher training. Copies of the 40-hour OSHA training records along with the documentation of any refresher training for contractor personnel will be requested prior to performing work at the site.

A8.2 Laboratory Certifications

A8.2.1 First Environmental Laboratories, Inc.

First's laboratory certificates are on file with Antea Group. First's documentation protocols are discussed in their QAM.

A8.2.2 Pace Analytical Services, Inc.

Pace's laboratory certificates are on file with Antea Group. Pace's documentation protocols are discussed in their QAM.

A9 – Documentation and Records

A9.1 Document Distribution and Retention

Each version of the QAPP/SAP will be numbered to ensure proper distribution and retrieval. The current version of the QAPP/SAP will be provided to the USEPA in electronic format. Antea Group will retain a hard copy of the final report in the active project file. Copies of the QAPP/SAP will be distributed to those on the Distribution List in electronic format.

Project files are maintained at the Antea Group office for one year following completion of the project. After one year, the file will be stored off-site for a minimum of ten years after contract expiration or cancellation. After ten years, the file will be purged of the majority of documents except for contracts, reports, regulatory correspondence, and original laboratory analytical reports.

A9.2 Laboratory Records

A9.2.1 First Environmental Laboratories, Inc.

Laboratory documentation requirements are delineated in the laboratory contracts and include specifications of data report composition, report format, turnaround time and records retention. First's documentation protocols are discussed in their QAM. The report will include blanks, spikes and matrix spike duplicates when sufficient sample volume is provided. The report will be provided in electronic format.

A9.2.2 Pace Analytical Services, Inc.

Laboratory documentation requirements are delineated in the laboratory contracts and include specifications of data report composition, report format, turnaround time and records retention. Pace's documentation protocols are discussed in their QAM. The report will include blanks, spikes and matrix spike duplicates when sufficient sample volume is provided. The report will be provided in electronic format.

Group B. Data Generation and Acquisition

B1 – Sampling Process Design

During this investigation, Antea Group will obtain environmental data from soil, surface water, and groundwater samples. Soil and groundwater sampling will be utilized to determine the horizontal and vertical extent of petroleum hydrocarbon impacts up gradient, in the source area, and down gradient of the release Site. Soil and surface water data will be utilized to determine the potential extent of petroleum hydrocarbon impacts in the ditches and surface water areas of the Site.

Sampling Analysis Breakdown – Soil and Water Samples

Laboratory	Matrix	VOC	PNA	TPH GRO	TPH DRO
Pace/First	Groundwater	X	X		
	Groundwater duplicate	X	X		
	Soil	X	X	X	X
	Soil duplicate	X	X	X	X
	Surface water	X	X		
	Surface water duplicate	X	X		
	Potable water	X	X		
	Potable water duplicate	X	X		
	Trip Blanks	X			

Additionally, soil and water samples will be obtained for characterization of investigative wastes. All soil and water samples will be kept in an ice packed cooler during the sampling process. Soil cuttings, bedrock cores, decontamination water, and purge water generated during field activities will be placed in 55-gallon drums (or other appropriate container) designated to contain either soil or liquid waste. The containers will be stored on the Site for the duration of the investigation and until analytical results, which will provide waste characterization information, are received. The disposal of the wastes will be coordinated following the completion of the field activities. Analysis to be performed for waste characterization samples to be obtained is described in the table below, but may be modified based on requirements of the designated disposal facility.

Sampling Analysis Breakdown – Investigation Derived Waste

Laboratory	Matrix	VOC	PNA	
First / Pace	Groundwater	X	X	
	Soil	X	X	

B2 – Sampling Methods

B2.1 Soil Boring and Monitoring Well Installation

Standardized boring and monitoring well installation procedures will be utilized in order to: (1) ensure comparable, uniform and reliable measurements; (2) assure data obtained in the field is complete and of satisfactory precision and accuracy; and, (3) allow traceability of error and correction of improper procedures.

B2.1.1 Measurement Point

The measurement datum utilized to reference geologic and sample depths will be the ground surface adjacent to each boring. The ground surface and monitoring well top of casing elevations will be surveyed with respect to a known data point to allow for calculation of groundwater flow directions. Relative ground surface elevations will be utilized for comparison of strata between borings and preparation of cross-sections. The location of the soil borings will be determined using a Trimble GeoXH or similar handheld GPS unit, with an accuracy of thirty (30) centimeters.

B2.1.2 Operation

Direct-push borings will be completed in accordance with American Society for Testing and Materials (ASTM) D6001-96 (*Standard Guide for Direct-Push Soil Sampling for Geoenvironmental Investigations* [2002]). Prior to any subsurface work, JULIE (Illinois One-Call System) will be contacted and the locations of all subsurface public utilities will be marked. A private locating service will mark on-site private utilities, if warranted. Prior to advancing the direct push borings, a hand auger or vacuum unit will be used to pothole 110% the diameter of the soil boring location to a minimum depth of 5 feet or to bedrock if encountered first to verify that no underground utilities are present.

Soil borings will be advanced using a track-mounted Geoprobe[®] rig. The Geoprobe rig is a hydraulically powered machine that utilizes static force and percussion to advance sampling tools into the subsurface. Geoprobe soil samples will be collected using a Macro-Core[®] Soil Sampler, which consists of a solid core barrel that has an assembled length of 52 inches and an outside diameter of 2.2 inches. The sampler is lined with a 1.7-inch diameter by 46-inch long, thin-walled clear acetate tube. The sample barrel and drive casing are pushed, pounded, or vibrated four (4) feet into the soil. The core barrel is then retrieved and the acetate liner containing the sample is removed. The liner is then cut lengthwise to expose the soil core for classification and screening. The sample barrel is then decontaminated with an Alconox[®]/potable water solution followed by a clean water rinse and a new, clean liner is installed in the core barrel. The washed sample barrel is then lowered to the bottom of the boring. This process is repeated until the desired total depth of the soil boring is reached. Following the 5 foot depth minimum pothole clearing as described in the

paragraph above, each soil boring will be advanced to bedrock refusal, which is anticipated to be one (1) to five (5) feet below ground surface.

Borings used for installation of monitoring wells will be advanced utilizing sonic drilling techniques. Sonic drilling will be accomplished utilizing sonic drill tooling supplied and operated by an Illinois licensed well driller. Soil and bedrock cores are retrieved from the sonic boreholes. No split barrel sampling is conducted, as the technique relies on collection of continuous cores to advance the drill tool. During drilling the core barrel is advanced ahead of an outer casing, sealing upper reaches of the borehole from lower units. Because the core barrel is smaller in diameter than the outer casing, the outer casing forms a tight seal with the formation, reducing the potential for vertical migration of contaminants. Soil and bedrock are continuously collected into the core barrel, brought to the surface in 5- to 10-foot intervals, and emptied into disposable plastic sleeves. In the field, soil and bedrock samples are described and logged on boring logs according to the Unified Soil Classification System and standard rock core logging methods by a Field Scientist. Soil cuttings and bedrock cores are drummed and stored on site for later disposal. The soil cuttings and bedrock cores will be properly disposed of by Wood River upon receipt of laboratory analytical results. Hazardous soil disposal will be separately contracted by Wood River after receipt of laboratory results, if necessary.

All down hole equipment utilized in soil borings and monitoring well installations is decontaminated prior to, and between uses, to prevent cross-contamination. Decontamination involves steam cleaning followed by water rinsing. Liquids and solids collected during decontamination will be containerized for future disposal.

Following completion of the borehole advancement, the monitoring wells will be installed into bedrock, which is anticipated at one (1) to five (5) feet bgs in some locations. The wells are anticipated to be installed to approximately 20 feet total depth. Actual well depths will be dependent on field conditions; Antea Group field personnel will work closely with the well drillers to assure the wells are constructed such that the wells are screened at a depth where there is sufficient water for monitoring and sampling.

The monitoring wells will be constructed in accordance with 77 Illinois Administrative Code 920.

All monitoring wells will be completed utilizing 4-inch diameter, plastic riser pipe with a 5 or 10-foot (0.010 inch slot) plastic screen. The wells will have appropriate filter pack material with 2-feet of filter pack extending above the screened interval. A 2-foot bentonite seal will be placed above the filter pack. Grout will fill the annular space from the top of the bentonite seal to within three (3) feet of the ground surface. Cement will be utilized to seal the remaining annular space and to secure a water-tight, above-grade

protective well casing on each well. All monitoring wells shall be completed as above grade stick-up wells.

After construction, the wells will be thoroughly developed to remove residual drilling materials from the borehole and to improve well performance by removing fine material from the filter pack that may pass into the well from the surrounding formation. Development of the wells will not occur any sooner than 48-hours after grouting is completed. Well development techniques will include pumping or bailing. All equipment utilized in development will be decontaminated prior to use to prevent cross-contamination.

All purge water will be placed into 55-gallon drums (or another appropriate container). A field technician will collect water samples from the drums for disposal criteria. Each drum will be labeled indicating the location (boring number) that the contents came from, and the date and time they were collected. The drums will be properly disposed of by Wood River upon receipt of laboratory analytical results. Hazardous water disposal will be separately contracted by Wood River after receipt of laboratory results, if necessary.

B2.1.3 Soil Screening

Soil samples obtained during drilling will be examined by a field technician and described by color, grain size and moisture content, as well as observed for visual evidence of petroleum hydrocarbon impacts. Soils are then classified in accordance with the Unified Soil Classification System. Soil screening for headspace analysis of ionizable organic vapors utilizing a PID will also be conducted. Bedrock samples will be described and logged on boring logs according to standard rock core logging methods.

As the acetate liners (or split-barrel samplers) are opened to expose the soil cores, a portion of the soil sample will be immediately containerized for field headspace screening and laboratory analysis. Nitrile gloves will be used and replaced between each sampling event. Soil samples will be described in general accordance with ASTM D5434-03 (*Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*) and ASTM D2488-00 (*Standard Practice for Description and Identification of Soils, Visual-Manual Procedure*) for the following information: sample depth, lithology, stratigraphy change, sediment color, moisture content, and indication of contamination. The lithology will include a detailed soil classification using the United Soil Classification System (USCS, ASTM D2487). This information will be used to develop a record of each soil boring.

Field screening of recovered soil samples will be conducted in general accordance with ASTM D5831-03 (*Standard Test Method for Screening Fuels in Soils*) to evaluate the possible presence of impacts. Soil samples collected for field screening by headspace method will be placed in self-sealing quart-size

polyethylene bags and filled so that the soil samples occupy approximately half of each bag's volume. Any visible soil clumps will be split. Following a headspace vapor development period of approximately 15 minutes, the soil samples will be screened using a MiniRAE 2000 by RAE Systems, Inc. of San Jose, CA, PID equipped with a 10.6 electron volt bulb, or equal. The PID is a trace gas analyzer capable of detecting total concentrations of VOCs to a minimum vapor concentration of approximately one (1) part per million (ppm). PID instrument specifications are provided in **Appendix B**. Soils will be screened by inserting the tip of the PID probe into the headspace of the bag samples and recording the highest meter readings. Headspace analysis will not be performed on the soil samples collected for laboratory analyses, but on replicate soil samples. The PID will be operated in accordance with the manufacturer's instructions and calibrated daily with a standard calibration gas (100 parts per million isobutylene) in a disposable cylinder. PID field calibration procedures are also provided in **Appendix B**.

A minimum of one (1) soil sample will be collected from each boring, from one (1) of the following two (2) intervals: 1) at the depth interval exhibiting the highest PID reading, based on field screening, and 2) at the interval immediately above the water table or bedrock, whichever is encountered first. If all PID readings are non-detect (background), one (1) soil sample will be collected from the interval immediately above the water table or bedrock whichever is encountered first.

B2.2 Groundwater Level Measurements

Standardized water level measurement procedures will be utilized at the monitoring wells in order to: (1) assure comparable, uniform and reliable measurements when taken on multiple occasions by various technical field personnel; (2) assure that data obtained in the field is complete and of satisfactory precision and accuracy; and, (3) allow traceability of error in water level measurement and correction of improper procedures.

In order to achieve undisturbed measurements, water levels will be gauged in all monitoring wells at least 48-hours after the new wells have been developed, which should allow ample recharge and equilibration of the groundwater table. Water level measurements will be obtained prior to purging (of existing wells) and sampling. The measurements will be collected from all wells within a 24-hour period to provide elevation data that is comparable.

B2.2.1 Measurement Point

The measurement point is a fixed point on top of the well casing from which all water level readings are recorded. If the measurement point is permanently marked on the casing rim, measurements will be collected from this location. If the measurement point is not marked, the highest point on the rim of the innermost well casing or, if level, the northern point of the casing rim will be utilized.

B2.2.2 Operation

An oil/water interface meter will be utilized to obtain both groundwater level measurements and the thickness of the free product, if present (H.Oil Oil/Water Interface Meter by Heron Instruments of Burlington, Ontario, Canada or similar). Oil/water interface meter specifications are provided in **Appendix**

C. The following guidelines for groundwater level measurement will be observed:

- The oil/water interface meter will be cleaned prior to use and between operation at each well. The probe and cable will be washed with an Alconox[®] and potable water solution followed by a potable water rinse and a final distilled or deionized water rinse.
- The field personnel will put on clean nitrile gloves.
- The electronic water sensor will be activated, and the probe will be slowly lowered into the well until the sensor produces an auditory and visual response indicating that the probe has contacted the water surface. The tape will be raised and lowered to confirm a consistent water level.
- The measurement to the top of the water column will be recorded on the field form to the nearest 0.01 foot when compared against the measuring point marked on the well casing.

The well depth will also be measured utilizing the same technique except that the probe will be lowered into the well until the weight of the probe is lessened, indicating that it has contacted the bottom of the well. The well depth will be recorded on the field data form to the nearest 0.01 foot.

B2.3 Groundwater Sampling Procedures

The purpose of a groundwater sampling quality assurance plan is to collect samples that are representative of existing conditions at the monitoring point. Every activity will be performed in a manner that minimizes the potential for the introduction of contaminants and maintains the sample integrity.

B2.3.1 Monitoring Well Purging

Well purging is critical to remove stagnant water in the well casing and to allow the collection of a sample that is representative of the water-bearing unit. The standard purge method will be utilized as described below. A disposable bailer will be utilized for purging shallow wells:

- Utilizing the groundwater level measurement data, the amount of water in a well volume will be calculated utilizing the equation $V = 7.48(\pi r^2 h)$ where V is well casing volume in gallons, r is the radius of the well casing in feet, and h is the height of the water column in the well in feet. This volume will be recorded on the field sampling form.
- The purging start time will be recorded on the field sampling form.
- The field personnel will put on clean nitrile gloves.
- Well purging utilizing a disposable bailer:
 - A new, disposable, high-density polyethylene bailer will be removed from its packaging and tied securely to the appropriate length of new retrieval line.
 - The bailer will be slowly lowered down the well casing until it fills with water.

- The bailer containing the water will be slowly removed from the well and the contents of the bailer will be emptied into a bucket.
- These processes are repeated until a minimum of three well casing volumes are extracted from the well.
- The volume of water removed from the well will be recorded on the field form.

Wells with extremely slow recharge rates will be purged by evacuating the well to near dryness and twice allowing it to partially recover.

B2.3.2 Monitoring Well Sample Collection

Once the monitoring wells have been purged, a water sample will be collected. The procedure for collecting groundwater samples in the shallow wells utilizing a bailer or low-flow sampling are described below:

Bailer Sampling

- A new, clean bailer will be lowered down the well casing and gently allowed to enter the water column. Care will be taken not to submerge the bailer to prevent mixing and to ensure water removal from the top of the water column.
- The bailer containing the water sample will be withdrawn gently from the water column and brought to the surface quickly.
- The sample will be transferred from the bailer to the sample container quickly while minimizing turbulence and exposure to the atmosphere.

Low-flow Sampling

- Dedicated disposal tubing will be used to purge wells, measure field parameters through a flow cell, and collect groundwater samples.
- Prior to sample collection, the flow cell will be disconnected and the sample will be collected directly into the sample container quickly while minimizing turbulence and exposure to the atmosphere.

Groundwater samples will be collected utilizing laboratory-supplied sample containers and preservatives. Samples will be collected by carefully removing the cap from the appropriate sample container. The interior of the sample bottle and cap will be protected to minimize the potential for contamination of the sample. If a sample container becomes compromised, the container will be discarded. Sample containers will be filled in a manner that minimizes turbulence, aeration and overfilling and will be filled to the appropriate level (i.e., no headspace)

B2.3.3 Ground Water Field Chemistry Measurements

A YSI 556 handheld multiparameter meter by YSI Incorporated of Yellow Springs, Ohio will be utilized to obtain field measurements of ground water chemistry parameters including temperature, conductivity, pH, and dissolved oxygen. Multiparameter meter instrument specifications are provided in **Appendix D**. The measurements will be collected in conjunction with monitoring well purging as described in Section

B2.3.1, will be recorded in the field notes, and will be provided in table format in the site investigation report.

B2.4 Surface Water Sampling

The surface water sampling will be conducted in the area, in order to delineate the full extent of petroleum hydrocarbon impacts. The exact locations of the future samples will be determined in the field based on site conditions; current locations are depicted on Figure 4. Additional sampling locations will be added if data indicates they are necessary.

A Geopump peristaltic pump by Geotech Environmental Equipment, Inc. of Denver, Colorado will be utilized for obtaining surface water samples from a location within the water column below the air-water interface. This procedure is intended to allow for collection of samples representative of the concentrations of dissolved constituents and avoid collection of any floating oil (light non-aqueous phase liquid [LNAPL]) or sheen, which could otherwise bias samples collected for this purpose. Peristaltic pump specifications are provided in **Appendix D**. Field protocols and sample collection are similar to those described for groundwater, with the exception of the procedures described below:

- New, clean tubing will be used for each sampling location;
- The collection end of the tubing will be placed in the middle of the water column at the sampling location (below the water line) in a manner that ensures no free product or sheen enters the tubing before pumping is initiated; and,
- Sample containers will be filled by allowing the pump discharge to flow gently down the side of the container.

A YSI 556 handheld multi-parameter meter by YSI Inc. of Yellow Springs, Ohio will be utilized to obtain field measurements of surface water chemistry parameters including temperature, conductivity, pH, and dissolved oxygen. Multi-parameter meter instrument specifications are provided in **Appendix D**. The measurements will be collected in conjunction with surface water sampling, will be recorded in the field notes, and will be provided in table format in the site investigation report.

B2.5 Receptor Survey

Antea Group identified potable water well receptors within ½-mile of the release as presented in Figure 5. Antea Group will prepare a complete receptor survey which will follow IEPA guidelines, and receptor survey data will be included in the site investigation report. As indicated in Tasks 4 and 5, a fact sheet is being distributed to local property owners, and groundwater samples are being collected from potable wells if agreed upon and/or requested by the property owners.

After the initial sampling event, groundwater samples via potable wells will be collected from an outside spigot or other location prior to any treatment of the well water (i.e. water softener or purifier, etc.). The well location and any treatment or other systems will be recorded in the field book.

The receptor survey data will be included in the site investigation report, including results and updates of the following tasks as needed:

- Walking survey – properties within 500 feet of the source;
 - Develop a base map illustrating properties and features;
 - Determine presence of water supply wells;
 - Verify use of existing supply wells, if any;
 - Ascertain presence of basements or sumps;
 - Contact residents/property owners to determine whether supply wells, basements, or sumps exist;
 - Document underground utility locations in study area;
 - Record presence and location of nearby surface water features; and,
 - Determine potential for other sources of contamination.
- Verify if public water supply connection present at properties within 500 feet of the site with the City of Kankakee Department of Public Works;
- Search the IEPA's GIS database for logs of community or potable wells within 1-mile of subject property; and,
- Search the IEPA's GIS database to determine whether the site is located within a regulated recharge area or wellhead protection area.

B2.6 Back-up Supplies or Equipment

Extra sample containers for groundwater, surface water, and soil sampling will be obtained prior to the field investigation in case of breakage or loss during sampling. In case of equipment failure, replacements will be obtained either by returning to the Antea Group office for a backup, or having the equipment driven to the sampling location by other Antea Group personnel.

B3 - Sample Handling and Custody

B3.1 Sample Handling

B3.1.1 Sample Identification and Numbering

All samples will be identified utilizing a unique location description (i.e., well name) followed by a sequential number:

- MW – Groundwater Monitoring Well (MW-1, etc.)
- SB – Soil Boring Sample (SB-1, etc.)
- SS- Over Excavation Soil Samples (SS-1, etc.)
- SW – Surface Water Samples

QC samples will be identified utilizing the following prefixes followed by a sequential number:

- TB – Trip Blank (TB-1, etc.)
- D – Field Duplicate Sample (MW-DUP-1; SB-DUP-1; SS-DUP-1, etc.)

B.3.1.2 Sample Containers, Preservation, and Holding Times

Table 1 details the size and type of sample containers required for the soil and groundwater analysis, as well as the preservation techniques and holding time requirements. All sampling containers and preservatives will be supplied by the analytical laboratory.

B.3.1.3 Sample Storage

All soil and groundwater sample containers will be packed in a sample storage cooler provided by the laboratory utilizing bubble-pack material to prevent breakage and cooled to $\leq 6^{\circ}\text{C}$ utilizing ice. Samples will be stored within a cooler or refrigerated from the time of collection until laboratory receipt.

B.3.1.4 Sample Transportation

Soil and water samples will be delivered or shipped to the laboratory via next-day delivery service within 24-hours of sample collection. Shipping receipts will be retained for all sample shipments.

B3.2 Chain-of-Custody

B3.2.1 Field Chain-of-Custody

B3.2.1.1 Sample Identification

Soil and Water Samples - A label will be attached to each sample container immediately following sample collection. Each label will specify the project identification number, sample location identification, date and time collected sampler's initials, preservation method and parameter(s) to be analyzed. An example of a sample label is provided in **Appendix E**.

B3.2.1.2 Field Logs

Field logs will be maintained throughout the monitoring and assessment program. Field measurements and other pertinent information regarding field activities will be recorded. An example of the *Groundwater Sampling Information Form* is provided in **Appendix F**.

B3.2.1.3 Chain-of-Custody

Antea Group field personnel will be responsible for custody of samples until they are properly dispatched to the laboratory or relinquished to an assigned custodian. The field personnel will ensure that possession of sample containers is maintained at all times or that the containers are stored in a secure area.

A chain-of-custody record is a printed form that accompanies a sample or group of samples as custody is transferred. All entries will be recorded in indelible ink.

First Environmental Laboratory, Inc./Pace Analytical Laboratories, Inc. - The original chain-of-custody record and two copies will be sealed in a waterproof container and shipped inside each sample storage cooler to identify the samples in the cooler and to summarize the analyses to be performed on each sample. One copy of the record will be retained by the field personnel. An example of a chain-of-custody form is provided in **Appendix E**.

B3.2.2 Laboratory Chain-of-Custody – Pace/First

B3.2.2.1 Sample Receipt

According to First's and Pace's respective QAMs, sample shipments are received at the sample receiving area. Sample custodians verify the number of sample storage coolers received against the numbers listed on the shipping manifest/chain-of-custody. Any damage to the coolers or other discrepancies observed are noted on the chain-of-custody.

B3.2.2.2 Sample Verification

Upon arrival of a sample shipment, sample control personnel perform a routine inspection. The inspection includes the documentation of custody seals or tapes, chain-of-custody, sample labels, agreement between sample labels and chain-of-custody, and condition of the samples when received.

B3.2.2.3 Sample Log-In

Upon completion of the sample receipt/custody procedures, all sample and analysis data must be complete and documented on the chain-of-custody for input into the Laboratory Information Management System (LIMS). All samples are logged into the LIMS within one working day of receipt. Samples are properly stored immediately upon receipt for staging to prevent sample degradation.

B3.2.2.4 Sample Disposal

The sample retention time is a minimum of 45 days after receipt of the sample. After this period expires samples are properly disposed of by First/Pace.

B3.2.5 Custody of Evidence File

All field data forms and laboratory analytical reports will be included in the site investigation report and submitted to the USEPA.

B4 – Analytical Methods

B4.1 Analytical Methods Requirements

Soil, surface water, and groundwater samples collected for the investigation program will be analyzed by the following methods as outlined in Table 1:

- VOC - USEPA Method 8260
- PNA – USEPA Method 8270 by SIM
- GRO USEPA Method 8015
- DRO USEPA Method 8015

Methods of sample preservation and analysis are conducted in accordance with guidelines described in First's and Pace's referenced laboratory protocols described in their QAM. Specific target analyte lists will be developed upon review and analysis of the ongoing crude oil analysis that is currently being conducted. The need for any additional analyses, such as TPH, will be evaluated as warranted.

Soil and water samples obtained for waste profiling purposes may be analyzed by the following methods as outlined in Table 1 as determined by the waste receiving facility:

- VOC – USEPA Method 8260
- PNA – USEPA Method 8270 by SIM
- Metals USEPA 6020
- TCLP benzene USEP 8260

B4.2 Quality Assurance/Quality Control Requirements

Quality control of laboratory analysis is ensured by performing analytical methods according to prescribed protocols, analyzing laboratory QA/QC samples to measure precision and accuracy of laboratory methods and equipment, instrument calibration, and preventive maintenance. These procedures are described below. Table 2 describes the batch QC samples that will be obtained.

B4.2.1 Analytical Methods

Laboratory analyses for each parameter will be performed in accordance with prescribed USEPA protocols established in the document *Test Methods for Evaluating Solid Waste, SW-846* (USEPA, January 1995).

Groundwater and Surface Water Samples

Groundwater and surface water samples will be analyzed for VOCs by USEPA Method 8260 and PNAs by USEPA Method 8270 by selective ion monitoring (SIM).

The groundwater and surface water contaminant concentration data will be evaluated against USEPA Region V ESL, IEPA TACO Criteria, or other relevant benchmarks that may be appropriate, and cleanup objectives will be developed. A list of USEPA Region V ESLs and IEPA Petroleum Cleanup Objectives for Sediment and Surface Water is included in the tables in **Appendix A** for reference.

Soil Samples

Soil samples will be analyzed for VOC by USEPA Method 8260, PNAs by USEPA Method 8270 by SIM, TPH-GRO, and TPH-DRO.

The soil contaminant concentration data will be evaluated against USEPA Region V ESL, IEPA TACO Criteria, or other relevant benchmarks that may be appropriate, and cleanup objectives will be evaluated. A list of USEPA Region V ESLs and IEPA Petroleum Cleanup Objectives for Sediment and Surface Water is included in the tables in **Appendix A** for reference.

Waste Profiling Samples

Soil and groundwater samples collected for waste profiling purposes will be submitted to First or Pace for chemical analysis as required by the designated disposal facility.

Methods have been selected to maximize the analysis sensitivity for specific hazardous constituents that may be present as well as to provide data that will be comparable to previous results obtained at the Site. All protocols for each method will be followed for each parameter, including method-specified holding times for extraction and analysis listed in Table 1.

B5 – Quality Control

Table 2 describes the number and frequency of samples to be obtained for quality control purposes. Acceptance criteria, corrective actions and the responsible persons are also described in Table 2.

Project acceptance criteria and QC measures are described in Section A7.2 (including formulae for RPD and percent recovery). If the QC measures are not met or cannot be rectified in the laboratory, additional sampling and analysis may be necessary.

B5.1 Field Quality Control Samples

B5.1.1 Trip Blank (Field Blank)

Water Samples - Trip blanks will be provided by the laboratory prior to each sampling event in the actual sample containers and will be kept with the investigative samples throughout the sampling event. Upon completion of groundwater sampling, the trip blank will be packaged for shipment with the groundwater samples and submitted for analysis. At no time after their preparation will the sample containers be opened before they reach the laboratory. The trip blank sample will be utilized to evaluate cross-contamination of samples during shipment and storage. The trip blank will be analyzed for VOC.

B5.1.2 Field Duplicate Samples

Duplicate samples are independent samples collected in such a manner that they are equally representative of the parameter of interest at a given point in space and time. Duplicate samples, when collected, will be processed and analyzed by the same laboratory, and provide intra-laboratory precision information for the entire measurement system including sample acquisition, homogeneity, handling, shipping, storage, preparation and analysis. Duplicate sampling efforts by media are described below:

- Groundwater Samples - One field duplicate will be collected and submitted to the laboratory as a blind sample (i.e., sampling location not identified on chain-of-custody). The field duplicate sample will be analyzed for VOC and PNA.
- Soil Samples - Two field duplicates will be collected and submitted to the laboratory as a blind sample (i.e., sampling location not identified on chain-of-custody). The field duplicate samples will be analyzed for VOC, PNA, TPH-GRO, and TPH-DRO.
- Surface Water and Potable Water Samples - One field duplicate will be collected and submitted to the laboratory as a blind sample (i.e., sampling location not identified on chain-of-custody). The field duplicate sample will be analyzed for VOC and PNA.

B5.2 Laboratory Quality Assurance/Quality Control Samples

First/Pace - Laboratory QA/QC samples that will be analyzed during the investigation by Pace include method blanks, matrix spikes and matrix spike duplicates, surrogates, laboratory control samples and laboratory control sample duplicates. The description and purpose of these samples is discussed below.

B5.2.1 Method Blanks

First/Pace - Method blanks are typically run at a minimum frequency of one (1) per 20 samples or every day, whichever is shorter. Each method blank is evaluated for contamination. The source of any contamination is investigated and documented corrective action is taken when the concentration of any target analyte is detected above the reporting limit and is greater than 1/10 of the amount of that analyte found in any associated sample. Corrective actions include the re-preparation and re-analysis of all the samples (where possible) along with the full set of required quality control samples. Data qualifiers must be applied to any result reported that is associated with a contaminated method blank. Table 2 describes the number and frequency of samples to be obtained for quality control purposes, acceptance criteria, corrective actions and the responsible persons.

B5.2.2 Matrix Spike Samples and Duplicate Matrix Spike Samples

First/Pace - Matrix spikes are prepared by the addition of known quantities of target analytes to a sample. The sample is extracted and analyzed. The results of the analysis are compared with the known additions and a matrix spike recovery is calculated. The recovery gives an evaluation of the accuracy of the extraction and analysis procedure. Typically, matrix spikes are performed in duplicate for organic analyses in order to evaluate the precision of the methods. Matrix spike recoveries are reviewed to check that they are within acceptable ranges. However, the acceptable ranges vary widely according to the analytical method and matrix. Matrix spike and matrix spike duplicate samples are typically run every 20 samples. Table 2 describes the number and frequency of samples to be obtained for quality control purposes, acceptance criteria, corrective actions and the responsible persons.

B5.2.3 Surrogate Samples

First/Pace - Surrogate analyses are generally run for each sample for organic analysis. Surrogates are organic compounds which are similar to the analytes of interest in chemical behavior, but which are not normally found in environmental samples. Surrogates are added to samples to monitor the effect of the matrix on the accuracy of the analysis. Results of surrogate analyses are reported in percent recovery. The laboratory establishes acceptable limits for surrogate recovery.

The surrogates are evaluated against the method or laboratory derived acceptance criteria, see applicable analytical SOP for criteria. Any surrogate compound that is outside of these limits is considered to be 'out of control' and must be qualified appropriately. Samples with surrogate failures are typically re-extracted and/or re-analyzed to confirm that the out-of-control value was caused by the matrix of the sample and not by some other systematic error. An exception to this would be samples that have high surrogate values but no reportable hits for target compounds. These samples would be reported, with a qualifier, because the implied high bias would not affect the final results. Table 2 describes the number and frequency of samples to be obtained for quality control purposes, acceptance criteria, corrective actions and the responsible persons.

B5.2.4 Laboratory Control Samples and Laboratory Control Sample Duplicates

First/Pace - Laboratory control samples are spiked samples with known amounts of specific analytes of interest. They are typically run at a frequency of one (1) per batch. They provide a measure of instrument accuracy since they are in a different matrix than the samples. The laboratory control sample is evaluated against the method default or laboratory-derived acceptance criteria. Method default control limits will be used until the laboratory has a minimum of 20 (preferably greater than 30) data points from which to derive internal criteria. Any compound that is outside of these limits is considered to be 'out of control' and must be qualified appropriately. Any associated sample containing an 'out-of-control' compound must either be re-analyzed with a successful laboratory control sample or reported with the appropriate data qualifier. Table 2 describes the number and frequency of samples to be obtained for quality control purposes, acceptance criteria, corrective actions and the responsible persons.

B6 - Instrument/Equipment Testing, Inspection and Maintenance

B6.1 Field Instruments and Equipment

A PID will be utilized to field screen soil collected from the soil borings and excavation. The PID will be operated in accordance with the manufacturer's instructions and calibrated daily with a standard calibration gas (100 parts per million isobutylene) in a disposable cylinder. PID field calibration procedures are also provided in **Appendix B**.

A water level indicator or oil/water interface meter will be utilized to obtain groundwater and/or free product level measurements. Instrument specifications and instructions are provided in **Appendix C**. The instructions provide an equipment check method to ensure the instrument is working.

A multi-parameter meter will be utilized to obtain field measurements of groundwater and surface water chemistry parameters including temperature, conductivity, pH, and dissolved oxygen. Multi-parameter meter instrument specifications are provided in **Appendix D**.

Equipment that is not working properly can be returned to the Antea Group office for a replacement, as needed. Any equipment failures will be documented in the field log book.

B6.2 Laboratory Instruments and Equipment

First's and Pace's QAMs includes SOP that identify the instrument testing, inspection and maintenance to be utilized for the required laboratory equipment. First and Pace will adhere to these laboratory SOP.

B7 – Calibration Procedures and Frequency

B7.1 Field Instruments and Equipment

Calibration is not required for the water level indicator or the peristaltic pump. The PID will be operated in accordance with the manufacturer's instructions and calibrated daily with a standard calibration gas (100 parts per million isobutylene) in a disposable cylinder. PID field calibration procedures are also provided in **Appendix B**.

The multi-parameter meter will be operated and calibrated in accordance with the manufacturer's instructions. The calibration data will be used to confirm the accuracy of the measurements and quantify any "drift" that may have occurred throughout the day. Dates and times of calibration, serial numbers, and calibration techniques will be entered into the field forms or equipment logbook. The calibration procedures will be performed in accordance with those specified in the user manual, which is provided in **Appendix D**.

B7.2 Laboratory Instruments and Equipment

First's and Pace's QAMs includes SOP that identify the appropriate instrumentation to be utilized for the required laboratory analyses. First and Pace will adhere to their laboratory SOP. Calibration of laboratory equipment will be based on approved written procedures included in First and Pace's SOP.

B8 – Inspection/Acceptance of Supplies and Consumables

Supplies critical to this project include laboratory soil and groundwater sampling containers from First and Pace. Sampling containers will be ordered for delivery to the Antea Group office prior to the start of field activities. The containers will be inspected upon receipt for the correct number and types of containers. Incorrect containers or incomplete sampling equipment will be identified during the inspection and correct containers will be ordered prior to the start of field activities.

B9 – Non-Direct Measurements

Antea Group identified potable water well receptors within ½-mile of the release as presented in Figure 5. Antea Group will prepare a complete receptor survey. The receptor survey data will be included in the site investigation report.

B10 – Data Management

Antea Group will receive the data from the laboratory and pass it through internal data validation, after which an electronic spreadsheet will be developed. Antea Group will then compare the electronic version of the data to the validated data and make any necessary changes.

Microsoft Excel[®] will be used for the transmittal and tracking of data. The data will be stored in electronic form as a Microsoft Excel[®] document, Equis Database, and will be filed with USEPA and Antea Group.

GROUP C: ASSESSMENT AND OVERSIGHT

C1 - Assessment and Response Actions

The following assessment activities will take place during performance of the site investigation and monitoring activities:

- Readiness review - prior to initiation of field work – to be performed by Antea Group
- Field performance assessment – during field work – to be performed by Antea Group
- Project data QA/QC – ongoing after the start of field work – to be performed by Antea Group
- Lab QA/QC – ongoing as project commences – to be performed by First and Pace

Readiness Review - A readiness review will take place prior to mobilization to the job site. A checklist of supplies, logistics, QA/QC measures, sampling protocols and other relevant issues will be reviewed and problems will be identified with time for correction prior to the sampling events and assessment activities.

Field Performance Assessment – Mr. Gary Schroehler and/or Mr. Kendall Rannaoja will be briefed daily on the status and progress of the current sampling event by the field/sampling crew leader. It will be their responsibility that all specified requirements are being fulfilled as outlined in this QAPP/SAP. Performance assessment of sampling events and assessment activities will be performed by the field/sampling crew leader.

Project Data QA/QC - The data will undergo internal QA/QC to identify any data quality problems. The Antea Group project managers (Mr. Gary Schroehler and/or Mr. Kendall Rannaoja) will make decisions with regard to modification and/or correction of any identified problems. Project data review will include initial review of analytical and field data for complete and accurate documentation, chain of custody procedures, analytical holding time(s) compliance and required frequency of field and laboratory QC samples.

Laboratory QA/QC - During the course of sample analysis completed during this work, the laboratories QA officer and team members will assure that all measurements and procedures are followed as specified in this QAPP and measurements meet the prescribed and accepted criteria. In the event a problem arises, prompt action to correct the immediate problem and identification of root causes will be imperative.

C2 - Reports to Management

First's and Pace's QAM describes their participation in the National Environmental Laboratory Accreditation Conference (NELAC)-defined proficiency testing (PT) program. According to the QAM, PT samples are obtained from approved providers and analyzed and reported at a minimum of two (2) times per year for the relevant fields of testing per matrix. The lab initiates an investigation whenever PT results are deemed 'unacceptable' by the PT provider. All findings and corrective actions taken are reported to the Quality Manager. A corrective action plan (including re-analysis of similar samples) is initiated and this report is sent to the appropriate state accreditation agencies for their review. PT samples are treated as typical client samples, utilizing the same staff, methods, equipment, facilities, and frequency of analysis. PT samples are included in the laboratory's normal analytical processes and do not receive extraordinary attention due to their nature.

GROUP D: DATA VALIDATION AND USABILITY

D1 - Data Review, Validation, and Verification Requirements

Only First/Pace-generated analytical data will be validated as a part of this assessment. The data validation will use USEPA National Functional Guidelines for Data Validation that contains the details on what technical data review criteria such as Precision, Accuracy, Representativeness and Completeness. Specifics on each criterion are discussed in Section A7. The laboratory analytical reports will provide values for Precision and Accuracy. Antea Group will review these values and the overall analytical results to determine Representativeness and Completeness of the sampling program.

D2 – Verification and Verification Methods

Antea Group project managers Mr. Gary Schroeher and/or Mr. Kendall Rannaoja will be responsible for resolving any data quality issues and working with the subcontractors as needed.

Antea Group will validate the data and verify the data meet the DQO for this project. Any qualified data or validation issues will be explained and documented in the reports/documents generated during the course of this assessment.

Antea Group will submit electronic copies of reports and data generated from this investigation to the USEPA.

The data may be subjected to various statistical analysis and/or modeling in support of risk analysis. In general, minimum, maximum, means, correlation with water levels, etc. may be generated. The specific statistical and/or modeling program used will be determined by the ultimate needs of the project and a full description will be documented in the final report.

D3 - Reconciliation with User Requirements

The main questions to be investigated at this site are: "What are the horizontal and vertical extent of petroleum hydrocarbon impacts at the Site?"; and, "What are the extent of petroleum hydrocarbon impacts in the surface water and groundwater of the Site?". With that focus in mind, the data obtained during the course of this assessment will be assessed to determine if these questions can be answered. Additional assessment may be required if the data is incomplete or does not meet the data quality objectives.

TABLES

TABLE 1

**Laboratory Analytical Method, Sample Container, Preservation, and Holding Time Summary
Route 113 Release
Limestone Township, Kankakee County, Illinois
Antea Group Project No.**

Parameter	Media	Analytical Method	Container	Preservation	Maximum Holding Time
VOC	Water (monitoring wells and surface water)	USEPA 8260	3 – 40 milliliter (mL) glass vials, with Teflon septum	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
VOC	Soil	USEPA 8260	40 mL glass vial	10 ml MeOH (cool to 4° C +/- 2° C)	14 days
VOC	Potable Water	USEPA 524.2	3 – 40 mL glass vials, with Teflon septum	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
PNA	Water (monitoring wells and surface water)	USEPA 8270	1 liter (L) glass	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
PNA	Potable Water	USEPA 625	1 liter (L) glass	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
PNA	Soil	USEPA 8270	4 ounce (oz.) Glass	(cool to 4° C +/- 2° C)	14 days
TPH-DRO	Soil	USEPA 8015B	4 oz. Glass	(cool to 4° C +/- 2° C)	14 days
TPH-GRO	Soil	USEPA 8015B	40 mL glass vial	10 ml MeOH (cool to 4° C +/- 2° C)	14 days

TABLE 2

**Quality Control Samples
Route 113 Release
Limestone Township, Kankakee County, Illinois
Antea Group Project No.**

Parameter	Frequency/ Number of Samples	Media/ Analyses	Method/SOP Acceptance Limits	Corrective Action	Person Responsible
Field Blank (Trip Blank)	1/day	Water	Sample container intact and at correct temperature; labeling requirements	Revise sample labeling as needed; consult with USEPA	Antea Group QA Officer / Amy Wrigley
Field Sample Duplicates	1 per 10 samples	Water/Soil	Sample container intact and at correct temperature; blind duplicate on chain-of- custody	Revise sample labeling as needed; consult with USEPA	Antea Group QA Officer / Amy Wrigley
Method Blanks	1 for every batch of 20 samples or less	Blank water or solid matrix	Nondetect below the reporting limit	Confirm that the detections are due to the method blank and not system related; reanalyze all associated samples that are not clean or 10x than the method blank detections. Qualify data accordingly.	Pace Project Manager/ Kang Khang First Project Manager Neal Cleghorn
Laboratory Control Samples (LCS)/ Laboratory Control Sample Duplicates (LCSD)	1 for every batch of 20 samples or less	Blank water or solid matrix	Pace internally generated limits	Confirm that the outliers are not system related; evaluate data impact – if LCS is high and samples are non- detect, no data impact; reanalyze all associated samples and qualify data accordingly.	Pace Project Manager/ Kang Khang First Project Manager Neal Cleghorn
Matrix Spikes (MS) / Matrix Spike Duplicates (MSD)	1 set per batch of 20 samples or less	Sample matrix	Pace internally generated limits	Confirm that the outliers are not system related; evaluate data impact. Qualify data accordingly. Batch is accepted based on LCS performance. The MS/MSD may be reflective of the parent sample matrix.	Pace Project Manager/ Kang Khang First Project Manager Neal Cleghorn
Surrogates	Every sample and QC		Pace internally generated limits	Confirm that the outliers are not system related; evaluate data impact. Reanalyze samples to confirm outliers, may be performed at dilutions to remove matrix interferants. Qualify data accordingly.	Pace Project Manager/ Kang Khang First Project Manager Neal Cleghorn

TABLES

TABLE 1

**Laboratory Analytical Method, Sample Container, Preservation, and Holding Time Summary
Route 113 Release
Limestone Township, Kankakee County, Illinois
Antea Group Project No.**

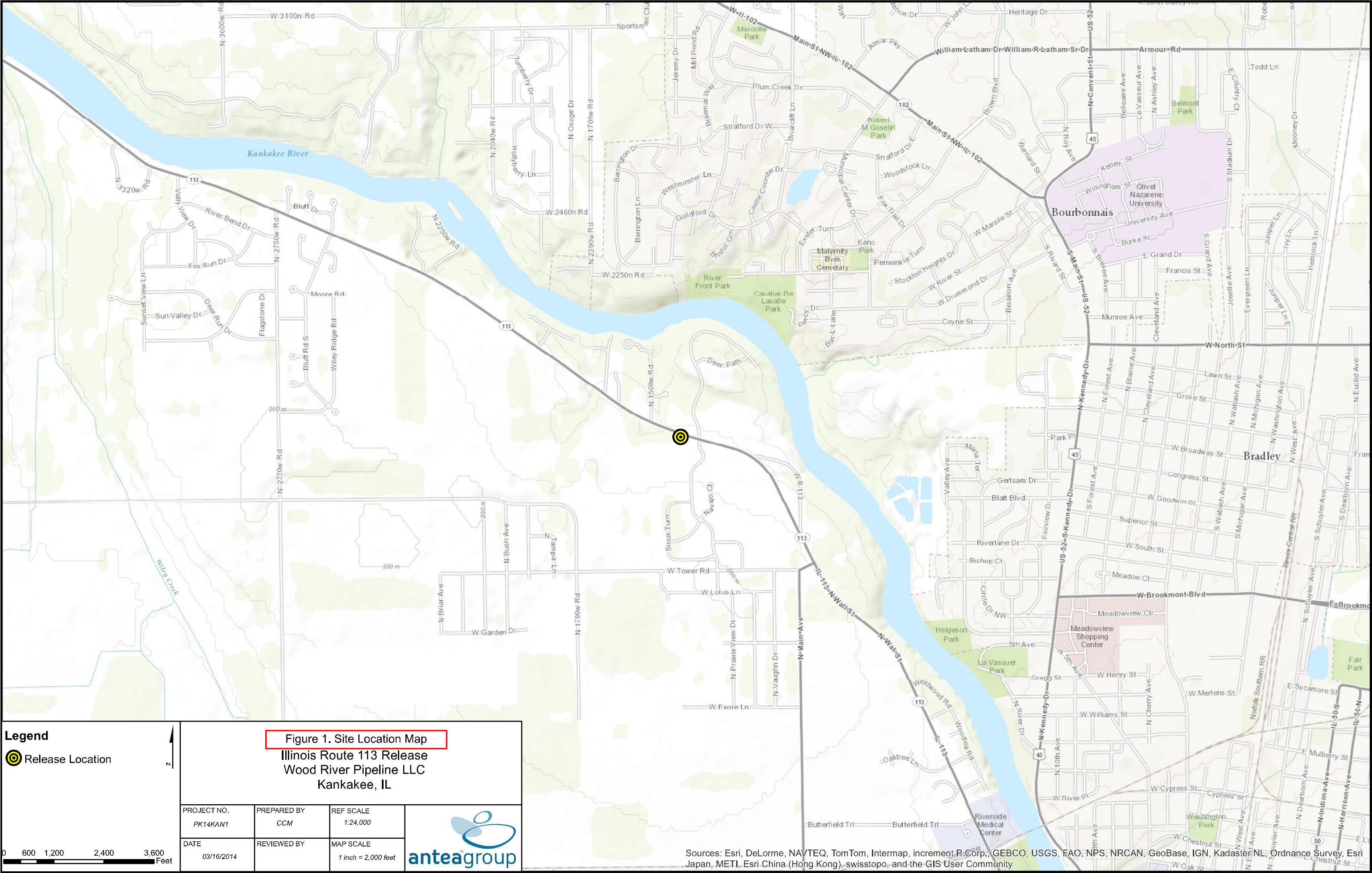
Parameter	Media	Analytical Method	Container	Preservation	Maximum Holding Time
VOC	Water (monitoring wells and surface water)	USEPA 8260	3 – 40 milliliter (mL) glass vials, with Teflon septum	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
VOC	Soil	USEPA 8260	40 mL glass vial	10 ml MeOH (cool to 4° C +/- 2° C)	14 days
VOC	Potable Water	USEPA 524.2	3 – 40 mL glass vials, with Teflon septum	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
PNA	Water (monitoring wells and surface water)	USEPA 8270	1 liter (L) glass	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
PNA	Potable Water	USEPA 625	1 liter (L) glass	HCl to pH<2 (cool to 4° C +/- 2° C)	14 days
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TPH-GRO	Soil	USEPA 8015B	40 mL glass vial	10 ml MeOH (cool to 4° C +/- 2° C)	14 days

TABLE 2

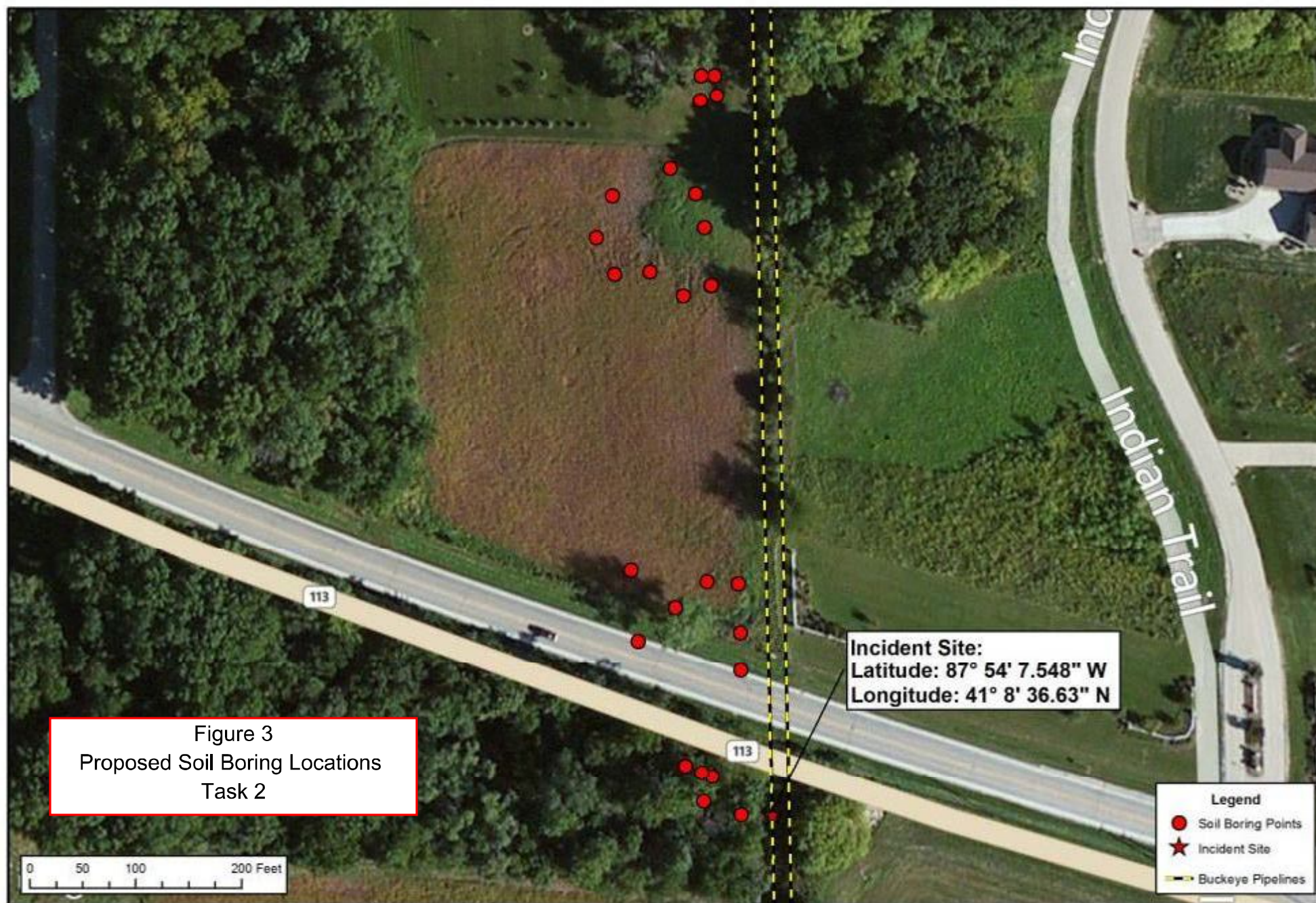
**Quality Control Samples
Route 113 Release
Limestone Township, Kankakee County, Illinois
Antea Group Project No.**

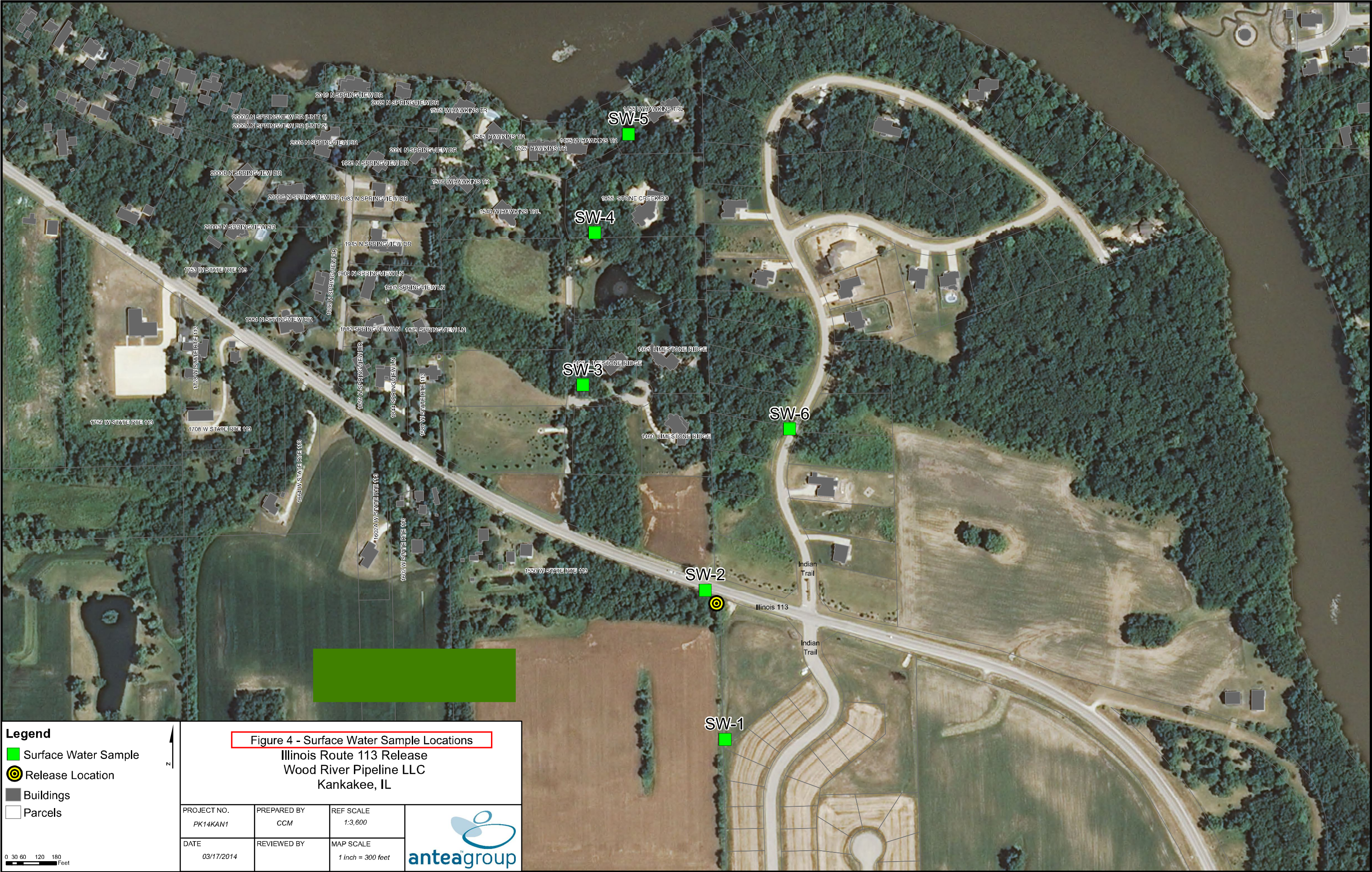
Parameter	Frequency/ Number of Samples	Media/ Analyses	Method/SOP Acceptance Limits	Corrective Action	Person Responsible
Field Blank (Trip Blank)	1/day	Water	Sample container intact and at correct temperature; labeling requirements	Revise sample labeling as needed; consult with USEPA	Antea Group QA Officer / Amy Wrigley
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Surrogates	Every sample and QC		Pace internally generated limits	Confirm that the outliers are not system related; evaluate data impact. Reanalyze samples to confirm outliers, may be performed at dilutions to remove matrix interferants. Qualify data accordingly.	Pace Project Manager/ Kang Khang First Project Manager Neal Cleghorn

FIGURES








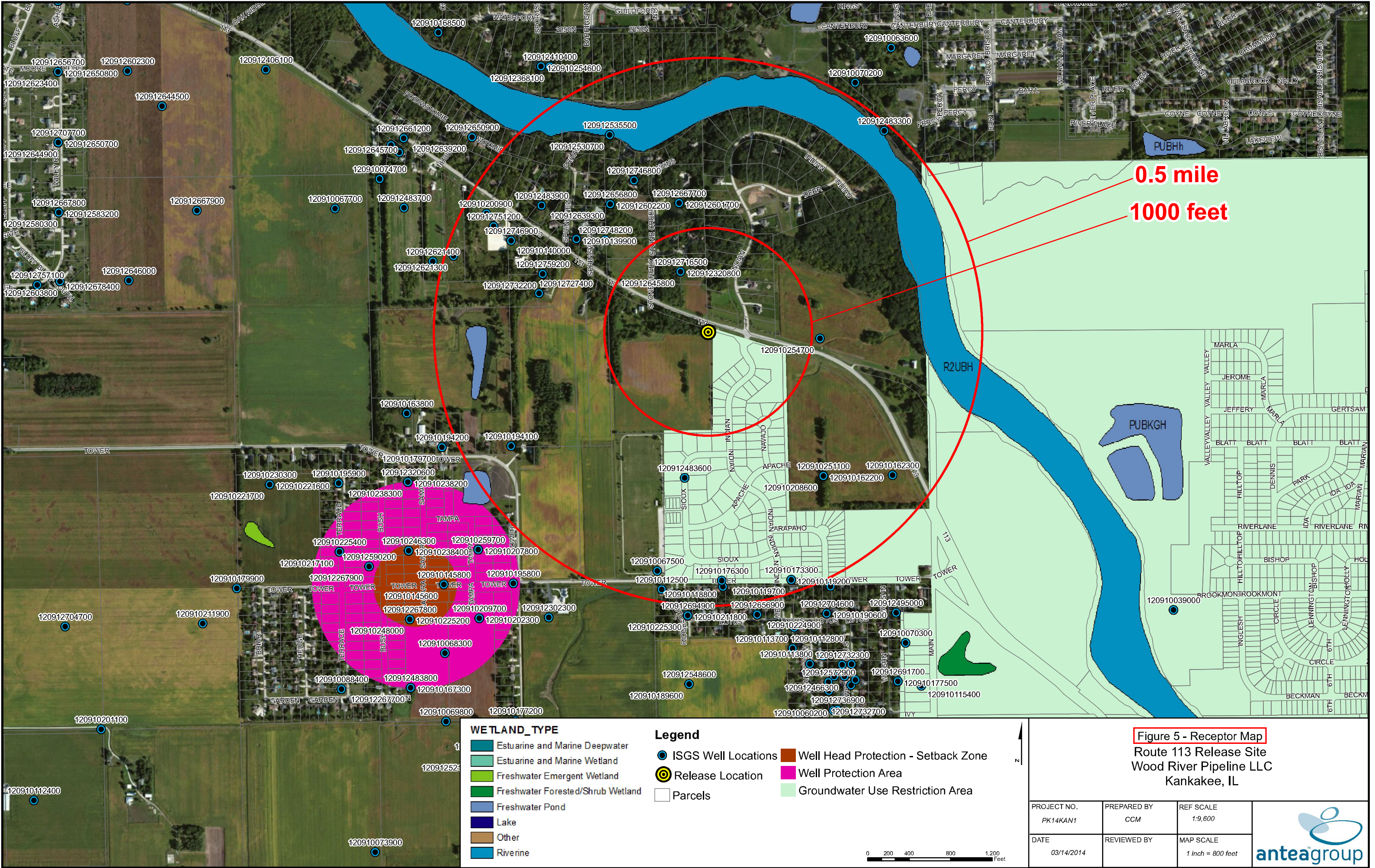


Legend

- Surface Water Sample
- Release Location
- Buildings
- Parcels

0 30 60 120 180 Feet

Figure 4 - Surface Water Sample Locations			
Illinois Route 113 Release			
Wood River Pipeline LLC			
Kankakee, IL			
PROJECT NO.	PREPARED BY	REF SCALE	
PK14KAN1	CCM	1:3,600	
DATE	REVIEWED BY	MAP SCALE	
03/17/2014		1 inch = 300 feet	



APPENDICES

APPENDIX A

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Acenaphthene	83-32-9		38^a	6.71 ^r	6.82 e+5
Acenaphthylene	208-96-8		4.84 e+3 ^b	5.87 ^r	6.82 e+5
Acetone	67-64-1	959	1700^{a, c, z}	9.9^z	2500 ^w
Acetonitrile	75-05-8	17.1	12 e+3^{d, z}	56^z	1370 ^w
Acetophenone	98-86-2		-----	-----	3 e+5
Acetylaminofluorene [2-]	53-96-3		535 ^b	15.3	596
Acrolein	107-02-8	0.578	0.19^{c, z}	1.52 e-3^z	5270 ^w
Acrylonitrile	107-13-1	0.797	66^a	1.2	23.9 ^w
Aldrin	309-00-2		1.7 e-2^{a, z}	2 ^t	3.32 ^x
Allyl chloride	107-05-1	1.22		-----	13.4
Aminobiphenyl [4-]	92-67-1			-----	3.05
Aniline	62-53-3		4.1^d	0.31	56.8 ^w
Anthracene	120-12-7		0.035^f	57.2^u	1.48 e+6
Antimony (Total)	7440-36-0		80^c		142
Aramite	140-57-8		3.09 ^g	1.11 e-3	1.66 e+5
Arsenic (Total)	7440-38-2		148^f	9790^u	5700
Azobenzene [p-(dimethylamino)]	60-11-7		1.65 ^b	318	40
Barium (Total)	7440-39-3		220^{d, z}		1040
Benzene	71-43-2	9.76	114 ^f	142	255
Benzo[a]anthracene	56-55-3		0.025^{c, z}	108^u	5210

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Benzo[a]pyrene	50-32-8		0.014 ^h	150^u	1520
Benzo[b]fluoranthene	205-99-2		9.07 ^b	1.04 e+4	5.98 e+4
Benzo[ghi]perylene	191-24-2		7.64 ^b	170 ^t	1.19 e+5
Benzo[k]fluoranthene	207-8-9		-----	240 ^t	1.48 e+5
Benzyl alcohol	100-51-6		8.6^{h, z}	1.04^z	6.58 e+4
Beryllium (Total)	7440-41-7		3.6^{d, k, z}		1060
BHC [alpha-]	319-84-6		12.4 ^b	6 ^t	99.4
BHC [beta-]	319-85-7		0.495 ^b	5 ^t	3.98 ^x
BHC [delta-]	319-86-8		667 ^g	7.15 e+4	9940
BHC [gamma-]	58-89-9		0.026^a	2.37^u	5 ^x
Bromodichloromethane	75-27-4			-----	540
Bromoform	75-25-2	9.11	230^{d, z}	492^z	1.59 e+4
Bromophenyl phenyl ether [4-]	101-55-3		1.5 ^h	1550	
Butylamine [N-Nitrosodi-n-]	924-16-3		-----	-----	267
Butylbenzyl phthalate	85-68-7		23^{d, z}	1970^z	239
Cadmium (Total)	7440-43-9		0.15^{i, j, k}	990^u	2.22
Carbon disulfide	75-15-0	3.67	15^{d, z}	23.9^z	94.1
Carbon tetrachloride	56-23-5	1.41	240^d	1450	2980
Chlordane	57-74-9		4.3 e-3^j	3.24^{u, z}	224 ^x
Chlorethyl ether [bis(2-)]	111-44-4		19 e+3^l	3520	2.37 e+4 ^w

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Chloro-1-methylethyl)ether [bis(2-]	108-60-1		-----	-----	1.99 e+4
Chloroaniline [p-]	106-47-8		232 ^g	146	1100
Chlorobenzene	108-90-7	120	47^a	291	1.31 e+4
Chlorobenzilate	510-15-6		7.16 ^g	860	5050
Chloroethane	75-0-3	20	-----	-----	
Chloroform	67-66-3	1.34	140^d	121	1190
Chloronaphthalene [2-]	91-58-7		0.396 ^b	417	12.2
Chlorophenol [2-]	95-57-8		24^a	31.9	243
Chlorophenyl phenyl ether [4-]	7005-72-3			-----	
Chloroprene	126-99-8	4.16 E-2		-----	2.9
Chromium ⁺³ (Total)	7440-47-3		42 ^{j, k}	4.34 e+4^u	400 ^y
Chrysene	218-1-9		-----	166^u	4730
Cobalt (Total)	7440-48-4		24^d	5.00 e+4 ^t	140
Copper (Total)	7440-50-8		1.58^{j, k, z}	3.16 e+4^u	5400
Cresol [4,6-dinitro-o-]	534-52-1		23^m	104	144
Cresol [m-]	108-39-4		62^d	52.4	3490
Cresol [o-]	95-48-7		67^c	55.4	4.04 e+4
Cresol [p-chloro-m-]	59-50-7		34.8 ^g	388	7950
Cresol [p-]	106-44-5		25^a	20.2	1.63 e+5
Cyanide	57-12-5		5.2 ^a	0.1 ^t	1330 ^w

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
DDD [4,4'-]	72-54-8		-----	4.88^{u, z}	758
DDE [4,4'-]	72-55-9		4.51 e-9 ^c	3.16^u	596
DDT [4,4'-]	50-29-3		1.1 e-5^{a, z}	4.16^u	3.5^z
Di-n-butyl phthalate	84-74-2		9.7^a	1114	150
Di-n-octyl phthalate	117-84-0		30 ^f	4.06 e+4	7.09 e+5
Diallate	2303-16-4		-----	-----	452 ^w
Dibenzofuran	132-64-9		4^{a, z}	449^z	
Dibenz[a,h]anthracene	53-70-3		-----	33^u	1.84 e+4
Dibromo-3-chloropropane [1,2-]	96-12-8	0.32	-----	-----	35.2
Dibromochloromethane	124-48-1		-----	-----	2050
Dibromoethane [1,2-]	106-93-4	176	-----	-----	1230
Dichloro-2-butene [trans-1,4-]	110-57-6	4.03		-----	
Dichlorobenzene [m-]	541-73-1	273	38^{a, z}	1315^z	3.77 e+4
Dichlorobenzene [o-]	95-50-1	270	14^h	294	2960
Dichlorobenzene [p-]	106-46-7	275	9.4^{d, z}	318^z	546
Dichlorobenzidine [3,3'-]	91-94-1		4.5^{a, z}	127	646
Dichlorodifluoromethane	75-71-8	1550		-----	3.95 e+4
Dichloroethane [1,1-]	75-34-3	1240	47 ^h	0.575	2.01 e+4
Dichloroethane [1,2-]	107-6-2	29.7	910^h	260	2.12 e+4
Dichloroethene [1,1-]	75-35-4	0.303	65^{a, z}	19.4^z	8280

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Dichloroethylene [trans-1,2-]	156-60-5	29.1	970^d	654	784
Dichlorophenol [2,4-]	120-83-2		11^{d, z}	81.7^z	8.75 e+4
Dichlorophenol [2,6-]	87-65-0			-----	1170
Dichloropropane [1,2-]	78-87-5	70.6	360^{a, z}	333^z	3.27 e+4
Dichloropropene [cis-1,3-]	10061-1-5	5.89	-----	-----	398
Dichloropropene [trans-1,3-]	10061-2-6	5.89	-----	-----	398
Dieldrin	60-57-1		7.1 e-5^a	1.9^{u, z}	2.38
Diethyl O-2-pyrazinyl phosphorothioate [O,O-]	297-97-2			-----	799
Diethyl phthalate	84-66-2		110^a	295	2.48 e+4
Dimethoate	60-51-5		-----	-----	218
Dimethyl phthalate	131-11-3		-----	-----	7.34 e+5
Dimethylbenzidine [3,3'-]	119-93-7			-----	104
Dimethylbenz[a]anthracene [7,12-]	57-97-6		0.548 ^b	6.64 e+4	1.63 e+4
Dimethylphenethylamine [alpha,alpha-]	122-9-8			-----	300
Dimethylphenol [2,4-]	105-67-9		100 ^b	304	10 ^x
Dinitrobenzene [m-]	99-65-0		22^d	8.61	655
Dinitrophenol [2,4-]	51-28-5		19^a	6.21	60.9
Dinitrotoluene [2,4-]	121-14-2		44^{d, z}	14.4^z	1280
Dinitrotoluene [2,6-]	606-20-2		81^d	39.8	32.8

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Dinoseb	88-85-7		0.48^a	14.5	21.8
Dioxane [1,4-]	123-91-1	367	22 e+3^a	119	2050 ^w
Diphenylamine	122-39-4		412 ^b	34.6	1010
Disulfoton	298-4-4		4.02 e-2 ^e	324	19.9
D [2,4-]	94-75-7		220^a	1273	27.2
Endosulfan I	959-98-8		0.056^j	3.26	119
Endosulfan II	33213-65-9		0.056^j	1.94	119
Endosulfan sulfate	1031-7-8		2.22 ^b	34.6	35.8
Endrin	72-20-8		0.036^a	2.22^{u, z}	10.1
Endrin aldehyde	7421-93-4		0.15 ^b	480^z	10.5
Ethyl methacrylate	97-63-2	356		-----	3 e+4
Ethyl methane sulfonate	62-50-0			-----	
Ethylbenzene	100-41-4	304	14^{o, z}	175	5160
Famphur	52-85-7			-----	49.7
Fluoranthene	206-44-0		1.9^{f, z}	423^u	1.22 e+5
Fluorene	86-73-7		19^d	77.4^u	1.22 e+5
Heptachlor	76-44-8		3.8 e-3^j	0.6 ^r	5.98
Heptachlor epoxide	1024-57-3		3.8 e-3^j	2.47^u	152
Hexachlorobenzene	118-74-1		3 e-4^a	20 ^t	199
Hexachlorobutadiene	87-68-3		0.053^{a, z}	26.5^z	39.8

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Hexachlorocyclopentadiene	77-47-4		77 ^b	901	755
Hexachloroethane	67-72-1		8^{a, z}	584^z	596
Hexachlorophene	70-30-4		0.228 ^e	2.31 e+5	199
Hexachloropropene	1888-71-7		-----	-----	
Hexanone [2-]	591-78-6	105	99^{h, z}	58.2^z	1.26 e+4
Indeno (1,2,3-cd) pyrene	193-39-5		4.31 ^b	200 ^t	1.09 e+5
Isobutyl alcohol	78-83-1	32.8	-----	-----	2.08 e+4 ^w
Isodrin	465-73-6		3.09 e-2 ^e	55.2	3.32 ^x
Isophorone	78-59-1		920^d	432	1.39 e+5
Isosafrole	120-58-1			-----	9940
Kepone	143-50-0		0.132 ^e	3.31	32.7
Lead (Total)	7439-92-1		1.17^{i, k, z}	3.58 e+4^u	53.7
Mercury (Total)	7439-97-6		1.3 e-3 ^a	174 ^r	100 ^y
Methacrylonitrile	126-98-7	3.38		-----	57 ^w
Methane [bis(2-chloroethoxy)]	111-91-1		-----	-----	302 ^w
Methapyrilene	91-80-5			-----	2780 ^w
Methoxychlor	72-43-5		0.019^h	13.6	19.9
Methyl bromide	74-83-9	26.5	16^d	1.37	235 ^w
Methyl chloride	74-87-3	2.63		-----	1.04 e+4 ^w
Methyl ethyl ketone	78-93-3	642	2200^{a, z}	42.4^z	8.96 e+4 ^w

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Methyl iodide	74-88-4	11.7		-----	1230
Methyl mercury	22967-92-6		2.46 e-3 ^e	0.01	1.58
Methyl methacrylate	80-62-6	87.1	2800 ^g	168	9.84 e+5 ^w
Methyl methanesulfonate	66-27-3			-----	315 ^w
Methyl parathion	298-0-0			-----	0.292
Methyl-2-pentanone [4-]	108-10-1	45.9	170^{h, z}	25.1^z	4.43 e+5
Methylcholanthrene [3-]	56-49-5		8.91 e-2 ^b	8.19 e+6	77.9
Methylene bromide	74-95-3	344		-----	6.5 e+4 ^w
Methylene chloride	75-9-2	4780	940^a	159^z	4050 ^w
Methylnaphthalene [2-]	91-57-6		330 ^b	20.2 ^r	3240
Naphthalene	91-20-3	80.1	13^{a, z}	176^u	99.4
Naphthoquinone [1,4-]	130-15-4		-----	-----	1670
Naphthylamine [1-]	134-32-7		-----	-----	9340
Naphthylamine [2-]	91-59-8			-----	3030
Nickel (Total)	7440-2-0		28.9^{i, k, z}	2.27 e+4^u	1.36 e+4
Nitroaniline [m-]	99-9-2			-----	3160
Nitroaniline [o-]	88-74-4			-----	7.41 e+4
Nitroaniline [p-]	100-1-6			-----	2.19 e+4
Nitrobenzene	98-95-3		220^{a, z}	145^z	1310
Nitrophenol [o-]	88-75-5		-----	-----	1600

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Nitrophenol [p-]	100-2-7		60^a	13.3	5120
Nitroquinoline-1-oxide [4-]	56-57-5			-----	122
Nitrosodiethylamine [N-]	55-18-5		768 ^g	22.8	69.3 ^w
Nitrosodimethylamine [N-]	62-75-9			-----	0.0321 ^w
Nitrosodiphenylamine [N-]	86-30-6		-----	-----	545
Nitrosomethylethylamine [N-]	10595-95-6			-----	1.66 ^w
Nitrosomorpholine [N-]	59-89-2			-----	70.6 ^w
Nitrosopiperidine [N-]	100-75-4			-----	6.65 ^w
Nitrosopyrrolidine [N-]	930-55-2			-----	12.6 ^w
Parathion	56-38-2		0.013^{a, d}	0.757	0.34 ^y
Pentachlorobenzene	608-93-5		0.019^{a, z}	24^z	497
Pentachloroethane	76-1-7	0.68	56.4 ^g	689	1.07 e+4
Pentachloronitrobenzene	82-68-8		-----	-----	7090
Pentachlorophenol	87-86-5		4.0^{j, p, z}	2.3 e+4^z	119
Phenacetin	62-44-2		-----	-----	1.17 e+4
Phenanthrene	85-1-8		3.6^f	204^u	4.57 e+4
Phenol	108-95-2	4.31	180^c	49.1	1.2 e+5
Phenylenediamine [p-]	106-50-3			-----	6160 ^w
Phorate	298-02-2		3.62 ^g	0.861	0.496
Phthalate [bis(2-ethylhexyl)]	117-81-7		0.3^{q, z}	182 ^r	925

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Picoline [2-]	109-6-8	140	-----	-----	9900 ^w
Polychlorinated biphenyls	1336-36-3		1.2 e-4^{a, z}	59.8^u	0.332
Polychlorinated dibenzo-p-dioxins	PCDD-S		2.78 e-7 ^b	0.011	1.99 e-4
Polychlorinated dibenzofurans	51207-31-9		-----	-----	0.0386
Pronamide	23950-58-5		-----	-----	13.6 ^x
Propionitrile	107-12-0	1.87	-----	-----	49.8 ^w
Propylamine [N-nitrosodi-n-]	621-64-7			-----	544
Pyrene	129-0-0		0.3 ^g	195^u	7.85 e+4
Pyridine	110-86-1	13.7	2380 ^g	106	1030 ^w
Safrole	94-59-7		-----	-----	404
Selenium (Total)	7782-49-2		5 ^j		27.6
Silver (Total)	7440-22-4		0.12^{f, z}	500 ^t	4040
Silvex	93-72-1		30^{a, z}	675^z	109 ^x
Styrene	100-42-5	0.946	32^{d, z}	254^z	4690
Sulfide	18496-25-8				3.58
Tetrachlorobenzene [1,2,4,5-]	95-94-3		3^{a, z}	1252^z	2020
Tetrachlorodibenzo-p-dioxin [2,3,7,8-]	1746-1-6		3 e-9^{a, z}	1.2 e-4^z	1.99 e-4
Tetrachloroethane [1,1,1,2-]	630-20-6	22.5	-----	-----	2.25 e+5
Tetrachloroethane [1,1,2,2-]	79-34-5	353	380^a	850	127
Tetrachloroethene	127-18-4	69	45^a	990	9920

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment</u> ^s ug/kg	<u>Soil</u> ^v ug/kg
Tetrachlorophenol [2,3,4,6-]	58-90-2		1.2^{a, z}	129^z	199
Tetraethyl dithiopyrophosphate	3689-24-5		13.9 ^b	560	596
Thallium (Total)	7440-28-0		10^a		56.9
Tin (Total)	7440-31-5		180^d		7620
Toluene	108-88-3	1040	253 ^f	1220^z	5450
Toluidine [5-nitro-o-]	99-55-8			-----	8730
Toluidine [o-]	95-53-4			-----	2970 ^w
Toxaphene	8001-35-2		1.4 e-4^{a, z}	0.077^z	119
Trichlorobenzene [1,2,4-]	120-82-1		30^{a, z}	5062^z	1.11 e+4
Trichloroethane [1,1,1-]	71-55-6	4170	76^{d, z}	213^z	2.98 e+4
Trichloroethane [1,1,2-]	79-0-5	11.6	500^{a, z}	518^z	2.86 e+4
Trichloroethylene	79-1-6	1220	47^{h, z}	112^z	1.24 e+4
Trichlorofluoromethane	75-69-4	5150		-----	1.64 e+4
Trichlorophenol [2,4,5-]	95-95-4			-----	1.41 e+4
Trichlorophenol [2,4,6-]	88-6-2		4.9^d	208	9940
Trichloropropane [1,2,3-]	96-18-4	3.32	-----	-----	3360
Trichlorophenoxyacetic acid [2,4,5-]	93-76-5		686 ^g	5.87 e+4	596
Triethyl phosphorothioate [O,O,O-]	126-68-1		58.2 ^b	189	818
Trinitrobenzene [Sym-]	99-35-4			-----	376 ^w
Vanadium (Total)	7440-62-2		12^{a, z}		1590

<u>Chemical</u>	<u>CAS No.</u>	<u>Air</u> mg/m ³	<u>Water</u> ug/l	<u>Sediment^s</u> ug/kg	<u>Soil^v</u> ug/kg
Vinyl acetate	108-5-4	359	248 ^g	13	1.27 e+4 ^w
Vinyl chloride	75-1-4	0.221	930^a	202	646
Xylenes (total)	1330-20-7	135	27^{d, z}	433^z	1 e+4 ^x
Zinc (Total)	7440-66-6		65.7^{j, k, z}	1.21 e+5^u	6620 ^y

^a = Michigan water quality standards, Rule 57 water quality values, July 23, 2003. Available at: http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11383--,00.html. The water ESL data for acenaphthene, BHC (gamma), cyanide and parathion are Michigan (final chronic value or FCV) Tier I criteria. Likewise, water ESL data for dieldrin, dioxin, DDT, endrin, hexachlorobenzene, hexachlorobutadiene, mercury, PCB's and toxaphene represent wildlife values (see Notes at end of these footnotes for dioxin, DDT, mercury and PCB's). All of the remaining data are Tier II values.

^b = Water Ecological Screening Level (ESL) based on exposure to a mink (*Mustela vison*).

^c = Indiana water quality standards, Title 327, Article 2, of the Indiana Administrative Code, Feb. 4, 2002.

Available at: <http://www.ai.org/legislative/iac/t03270/a00020.pdf>. The water ESL for toxaphene is from the Indiana chronic aquatic criterion for all waters outside of mixing zones (see Table 1 under Rule 1 of 327 IAC 2-1-6 Minimum Surface Water Quality Standards at the above Internet site). The remaining water ESL data are either wildlife values (for dioxin, DDT, mercury and PCB's) or Tier II values for the Indiana Great Lakes Basin (see Great Lakes Basin Criteria and Values Table as developed under Rule 1.5 of 327 IAC Article 2 as referenced above).

^d = Ohio water quality standards, Chapter 3745-1 of the Ohio Administrative Code, Dec. 30, 2002. Available at: <http://www.epa.state.oh.us/dsw/rules/3745-1.html>. The water ESL data for endrin and parathion are Ohio aquatic life Tier I criteria from the Outside Mixing Zone Average (OMZA). Wildlife values are available for dioxin, DDT, mercury and PCB's. All of the remaining data are Ohio aquatic life Tier II values from the OMZA. See Ohio summary tables for water quality criteria and values along with reference on the development of Tier I criteria and Tier II values.

^e = Water ESL based on exposure to a belted kingfisher (*Ceryle alcyon*).

^f = Minnesota water quality standards, Rule 7052.0100, Subpart 2 (water ESL data for arsenic & benzene represents aquatic life chronic standards and dioxin, DDT, mercury and PCB's represents wildlife values), April 13, 2000. Rule 7050.0222, Subpart 2, Feb. 12, 2003. Available at:

<http://www.revisor.leg.state.mn.us/arule/7050/0100.html> and

<http://www.revisor.leg.state.mn.us/arule/7052/0222.html>

^g = Region 5, RCRA Interim Criteria, based on Aquire database with acceptable review codes and endpoints (life cycle). Must have eight or more acceptable studies (i.e., chronic and/or acute).

^h = GLWQI Tier II value as presented in: Suter, G.W. II and Tsao, C.L. 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota, 1996 Revision. ES/ER/TM-96/R2. Available at: <http://www.esd.oml.gov/programs/ecorisk/ecorisk.html>

ⁱ = U.S. EPA 2001 Update of Ambient Water Quality Criteria for Cadmium (EPA 822-R-01-001).

^j = U.S. EPA National Recommended Water Quality Criteria: 2002 (EPA 822-R-02-047)

^k = For hardness-dependent metals (beryllium, cadmium, chromium⁺³, copper, lead, nickel and zinc), freshwater chronic criteria are based on soft water with a total hardness of 50 mg/L as CaCO₃. Soft water is common within Region 5 and this water ESL may be recalculated when site specific water hardness is less than 50 mg/L.

^l = U.S. EPA Ambient Water Quality for Chloroalkyl Ethers (EPA 440/5-80-030). No definitive data available concerning chronic toxicity. The water ESL is based on no adverse effects for a chronic toxicity embryo-larval test of the fathead minnow.

^m = U.S. EPA Ambient Water Quality for Nitrophenols (EPA 440/5-80-063). The acute value of 230 ug/l was adjusted with an uncertainty factor of ten for 2,4-dinitrophenol and 4,6-dinitro-o-cresol since no chronic criteria are available.

ⁿ = Wisconsin Surface Water Quality Criteria and Secondary Values for Toxic Substances, NR 105.07(1)(b), Sept.1, 1997. Available at: <http://www.legis.state.wi.us/rsb/code/nr/nr100.html>

^o = Illinois water quality standards, Title 35, Part 302.208, Dec. 20, 2002. Available at: <http://www.ipcb.state.il.us/SLR/IPCBAandIEPAEnvironmentalRegulations-Title35.asp>

^p = The criterion for pentachlorophenol is pH dependent and is based on a pH of 6.5.

^q = U.S. EPA Ambient Water Quality for Phthalate Esters (EPA 440/5-80-067). A chronic value of 3 ug/L that resulted in significant reproductive impairment was adjusted with an uncertainty factor of ten.

^r = Environment Canada. September 1994. Interim Sediment Quality Assessment Values. Ecosystem Conservation Directorate. Evaluation and Interpretation Branch.

^s = Unless noted otherwise, all Sediment ESLs were derived using equilibrium partitioning (EqP) equation and the corresponding water ESL. Note: Sediment ESL = $K_{oc} \times \text{Water ESL} \times 0.01$.

^t = Ontario Ministry of the Environment. August 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.

^u = Consensus based threshold effect concentrations (TEC) as presented in MacDonald et. al. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch Environ Contam Toxicol 39:20-31 (see Table 2). The TEC for mercury had a high incidence of toxicity and was not used. These values do not consider bioaccumulation nor biomagnification.

^v = Unless noted otherwise, all Soil ESLs are based on exposure to a masked shrew (*Sorex cinereus*).

^w = Soil ESL is based on exposure to a meadow vole (*Microtus pennsylvanicus*).

^x = Soil ESL is based on exposure to a plant.

^y = Soil ESL is based on exposure to soil invertebrates (e.g., earthworms).

^z = New ESL data is lower than the previous table.

Notes: New ESL data are displayed in bold font and a dashed line (e.g., ----) is used to show when data was deleted from the previous table (i.e., supporting data was inadequate). All six states in EPA Region 5 have the same water ESL's for dioxin, DDT, mercury and PCB's which are based on a wildlife value. A summary report will be created on the development of soil benchmarks including equations, criteria and references. Likewise, a report will be prepared on the development of water benchmarks that are based on mink and belted kingfisher exposure.

Table 1

Petroleum Cleanup Objectives for Soil (TACO Tier I) and Sediment (Tier III) in mg/kg (ppm)
(Updated 6/10/10)

Chemical	Surface Soil (residential)*		Soil Component of GW Ingestion*	
	Ingestion	Inhalation #	Class I GW	Class II GW
Benzene	12	0.8	0.03	0.17
Toluene	16,000	42	12	29
Ethylbenzene	7,800	58	13	19
Xylenes	16,000	5.6	150	150
Acenaphthene	4,700	C	570	2,900
Anthracene	23,000	C	12,000	59,000
Benzo(a)anthracene +	0.9	C	2	8
Benzo(b)fluoranthene +	0.9	C	5	25
Benzo(k)fluoranthene	9	C	49	250
Benzo(a)pyrene +	0.09	C	8	82
Chrysene	88	C	160	800
Dibenzo(a,h)anthracene +	0.09	C	2	7.6
Fluoranthene	3,100	C	4,300	21,000
Fluorene	3,100	C	560	2,800
Indeno(1,2,3-c,d)pyrene +	0.9	C	14	69
Naphthalene	1,600	1.8	12	18
Pyrene	2,300	C	4,200	21,000
Methyl tertiary-butyl ether	780	140	0.32	0.32
Chloride	—	—	200**	200**
Sulfate	—	—	400**	400**

* Must also meet soil attenuation capacity (TPH<6000 mg/kg in top meter of TPH<2000 mg/kg below one meter 35 IAC 742.215)

+ As an alternative, statewide background values when greater may be substituted for health-based cleanup objectives for soil only

When lower, the construction worker objective is used (35 IAC 742 Appendix B, Table A, Notation x)

** TCLP or SPLP test results may be used

C = No toxicity criteria available for the route of exposure

ND = not determined because of insufficient toxicity data

Illinois Soil Background Values for Select (PNAs)			
Chemical Name	City of Chicago - 1	Metro Areas - 2	Non-Metro Areas - 3
Benzo(a)anthracene	1.1	1.8	—
Benzo(b)fluoranthene	1.5	2.0	—
Benzo(a)pyrene	1.3	2.1	0.98
Dibenzo(a,h)anthracene	0.20	0.42	0.15
Indeno(1,2,3-c,d)pyrene	—	1.6	—

^a Can only be used for areas of population densities of at least 1000 people per square mile and a minimum population of at least 10,000

1 Within the corporate limits of the city of Chicago

2 Counties within Metropolitan Statistical Areas (See TACO 742. Appendix A, Table G)

3 Counties outside of Metropolitan Statistical Areas

PNAs = Polynuclear Aromatic Hydrocarbons

TACO = Tiered Approach to Corrective Action Objectives

mg/kg = milligrams per kilogram

ppm = parts per million

Table 2
Petroleum Cleanup Objectives for Groundwater and Surface Water in mg/L
(Updated 9/15/09)

Chemical Name	Groundwater Remediation		Water Quality Standards/Criteria	
	Class I	Class II	Chronic Aquatic Life	Human Health
Benzene	0.005	0.025	0.86	0.31
Toluene	1.0	2.5	0.60	ND
Ethylbenzene	0.7	1.0	0.014	ND
Xylenes (total)	10.0	10.0	0.360	ND
Acenaphthene	0.42	2.1	0.062	ND
Anthracene	2.1	10.5	0.00053	35.0
Benzo(<i>a</i>)anthracene	0.00013	0.00065	ND	0.00016
Benzo(<i>b</i>)fluoranthene	0.00018	0.0009	ND	0.00016
Benzo(<i>k</i>)fluoranthene	0.00017	0.00085	ND	0.0016
Benzo(<i>a</i>)pyrene	0.0002	0.002	ND	0.000016
Chrysene	0.0015	0.0075	ND	0.016
Dibenzo(<i>a,h</i>)anthracene	0.0003	0.0015	ND	0.000016
Fluoranthene	0.28	1.4	0.0018	0.12
Fluorene	0.28	1.4	0.016	4.5
Indeno(1,2,3- <i>c,d</i>)pyrene	0.00043	0.00215	ND	0.00016
Naphthalene	0.14	0.22	0.068	ND
Pyrene	0.21	1.05	ND	3.5
Methyl tertiary-butyl ether	0.07	0.07	6.7	ND
Chloride	200	200	500 (250 if near a public water supply)	
Sulfate	400	400	Site Specific	

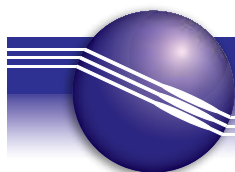
ND = standard or criterion not available

Groundwater standards from 35 IAC 620, Objectives from 35 IAC 742 Appendix B Table E.

Surface Water standards from 35 IAC 302, Criteria from IEPA internal document.

mg/l = milligrams per liter

APPENDIX B



MiniRAE 2000

Portable Handheld VOC Monitor

The rugged MiniRAE 2000 is the smallest pumped handheld volatile organic compound (VOC) monitor on the market. Its Photoionization Detector's (PID) extended range of 0 to 10,000 ppm makes it an ideal instrument for applications from environmental site surveying to HazMat/Homeland Security.

Key Features

- **Proven PID technology** The patented sensor provides a 3-second response up to 10,000 ppm and sets a new standard for resistance to moisture and dirt.
- **Wireless communication enabled and certified**
- **Self-cleaning lamp and sensor** The patented self-cleaning lamp and sensor minimize the need for maintenance and calibration.
- **The MiniRAE 2000 lamp and sensor can be taken apart in seconds for easy maintenance without tools!**
- **Measure more chemicals than with any other PID.** With over 100 Correction Factors built into the MiniRAE 2000 memory and the largest printed list of Correction Factors in the world (300+), RAE Systems offers the ability to accurately measure more ionizable chemicals than any other PID. When a gas is selected from the MiniRAE 2000's library, the alarm points are automatically loaded into the meter.
- **User friendly** screens make it easy to use for simple applications and flexible enough for sophisticated operations.
- **Drop-in battery** When work schedules require putting in more than the 10 hours supplied by the standard NiMH battery, the drop-in alkaline pack supplied with every MiniRAE 2000 lets you finish the job.
- **Rugged Rubber Boot** The standard rubber boot helps assure that the MiniRAE 2000 survives the bumps and knocks of tough field use.
- **Strong, built-in sample pump** draws up to 100 feet (30 m) horizontally or vertically.
- **Tough, flexible inlet probe**
- **Large keys** operable with 3 layers of gloves.
- **Easy-to-read display** with backlight.
- **Stores up to 267 hours of data** at one-minute intervals for downloading to PC.
- **3-year 10.6 eV lamp warranty**

Applications

HazMat/Homeland Security

- Initial PPE (personal protective equipment) assessment
- Leak detection
- Safety perimeter establishment and maintenance
- Spill delineation
- Decontamination
- Remediation

Industrial Hygiene/Safety

- Confined Space Entry (CSE)
- Indoor Air Quality (IAQ)
- Worker exposure studies

Environmental

- Soil and water headspace analysis
- Leaking underground storage tanks
- Perimeter fence line monitoring
- Fugitive emissions (EPA Method 21)
- Vapor recovery breakthrough
- Landfill monitoring

 **AutoRAE Compatible**

 **Wireless**



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ATEX



MiniRAE 2000

Specifications*

Detector Specifications

Size	8.2" L x 3.0" W x 2.0" H (21.8 x 7.62 x 5.0 cm)
Weight	20 oz with battery pack (553 g) w/o rubber boot
Sensor	Photoionization sensor with standard 10.6 eV or optional 9.8 eV or 11.7 eV UV lamp
Battery	<ul style="list-style-type: none">• Rechargeable, external, field-replaceable Nickel-Metal-Hydride (NiMH) battery pack• Alkaline battery holder (for 4 AA batteries)
Operating Period	10 hours continuous operation
Display	Large LCD, backlight activated manually, by alarms or by darkness
Keypad	1 operation and 2 programming keys
Direct Readout	<ul style="list-style-type: none">• VOCs as ppm by volume• High and low values• STEL and TWA (in hygiene mode)• Battery and shut down voltage
Alarms	<p>90 dB buzzer and flashing red LED to indicate exceeded preset limits:</p> <ul style="list-style-type: none">• High: 3 beeps and flashes per second• Low: 2 beeps and flashes per second• STEL and TWA: 1 beep and flash per second• Alarms automatic reset or latching with manual override• Optional plug-in pen size vibration alarm• User adjustable alarm limits
Calibration	Two-point field calibration of zero and standard reference gas. Calibration memory of 8 calibration gases, alarm limits, span values and calibration date
Datalogging	267 hours (at one-minute intervals) with date/time. Header information includes monitor serial number, user ID, site ID, date and time
Sampling Pump	<ul style="list-style-type: none">• Internal, integrated flow rate of 400 cc/min• Sample from 100' (30 m) horizontally or vertically
Low Flow Alarm	Auto shut-off pump at low flow condition
Communication	Download data and upload instrument set-up from PC through RS-232 link to serial port. Wireless communication enabled and certified (requires RAElink2 and ProRAE Remote to use)
Temperature	14° F to 104° F (-10° C to 40° C)
Humidity	0% to 95% relative humidity (non-condensing)
EM/RFI	Highly resistant to EMI/RFI. Compliant with EMC Directive 89/336/EEC
IP-rating	IP-55: protected against dust, protected against low-pressure jets of water from all directions
Hazardous Area Approval	<ul style="list-style-type: none">• US and Canada: UL and cUL, Classified for use in Class I, Division 1, Groups A, B, C and D hazardous locations• Europe: ATEX II IG EEx ia IIC T4
Attachment	Durable bright yellow rubber boot w/belt clip & wrist strap
Warranty	Lifetime on non-consumable components (per RAE Systems Standard Warranty), 3 years for 10.6V PID lamp, 1 year for pump and battery

* Specifications are subject to change

** Performance based on isobutylene calibration

Default Sensor Settings**

Gas Monitor (ppm)	Range (ppm)	Resolution Time (T90)	Response
VOCs	0 to 99.9 ppm	0.1 ppm	< 3 sec
	100 to 10,000 ppm	1 ppm	< 3 sec

MiniRAE 2000 and Accessories

Monitor only includes:

- RAE Systems UV lamp: 10.6 eV, 9.8 eV or 11.7 eV as specified
- ProRAE Suite software package for Windows® 98, NT, 2000 and XP
- Computer interface cable
- 5-inch Flex-I-Probe
- External filter
- Rubber boot with belt clip
- Alkaline battery adapter
- Tool kit
- Lamp cleaning kit
- Nickel-Metal-Hydride (NiMH) battery
- 120/230 V AC/DC wall adapter (if specified)
- Operation and maintenance manual

Monitor with accessories kit adds:

- Hard transport case with pre-cut foam padding
- 5 porous metal filters and O-rings
- Organic vapor zeroing adapter
- Gas outlet port and tubing

Optional calibration kit adds:

- 10 ppm isobutylene calibration gas, 34L
- Calibration regulator and flow controller

Optional Guaranteed Cost of Ownership Program:

- 4-year repair and replacement guarantee
- Annual maintenance service

DISTRIBUTED BY:

ver12_04.07

RAE Systems Inc.	USA/Canada	1-877-723-2878
3775 North First Street	Europe/Russia	+45 8652 5155
San Jose, CA 95134 USA	Middle East/Australia	971 50 429 1385
raesales@raesystems.com	China	8610 58858788
	Asia	+852 2669 0828

www.raesystems.com



MiniRAE 2000

Portable VOC Monitor PGM-7600



OPERATION AND MAINTENANCE MANUAL

(Document No.: 011-4001-000)
Revision E, May 2005



ATTENTION!

For European Applications

- A. CE 0575 II 1G/2G
DEMKO 03 ATEX 0204759X
Eex ia IIC T4**
- B. Recharge batteries only in non-hazardous locations.**
- C. Do not connect external cable to serial interface jack in hazardous locations.**
- D. Use RAE Systems Adapter P/N 500-0072 for connection to communication port and charging jack only in a non-hazardous area.**

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WARNING



- Do NOT proceed before reading -

This manual must be carefully read by all individuals who have or will have the responsibility for using, maintaining, or servicing this product.

The product will perform as designed only if it is used, maintained, and serviced in accordance with the manufacturer's instructions.

CAUTION!!

To reduce the risk of electric shock, turn off power before removing the monitor cover. Disconnect the battery before removing sensor module for service. Never operate the monitor while the cover is removed. Remove monitor cover and sensor module only in an area known to be non-hazardous.

The model PGM-7600 equipment is classified as to intrinsic safety for use in class I, division 1, groups A, B, C, D, or non-hazardous locations only.

Special Notes

-1-

When the MiniRAE 2000 Monitor is taken out from the transport case and turned on for the first time, there may be some residual organic or inorganic vapor trapped inside the detector chamber. The initial PID sensor reading may indicate a few ppm. Enter an area known to be free of any organic vapor and turn on the monitor. After running for several minutes, the residual vapor in the detector chamber will be cleared and the reading should return to zero.

-2-

The battery of the MiniRAE 2000 monitor will discharge slowly even if it is turned off. If the monitor has not been charged for 5-7 days, the battery voltage will be low. Therefore, it is a good practice to always charge the monitor before using it. It is also recommended to fully charge the monitor FOR AT LEAST 10 HOURS before first use. See Section 7 for more information on battery charging and replacement.

WARNINGS

STATIC HAZARD: Clean only with damp cloth.

For safety reasons this equipment must be operated and serviced by qualified personnel only. Read and understand instruction manual completely before operating or servicing.

Use only RAE Systems battery packs, part nos. 012-3050, 012-3051 or 012-3052. This instrument has not been tested in an explosive gas/air atmosphere having an oxygen concentration greater than 21%. Substitution of components may impair intrinsic safety. Recharge batteries only in non-hazardous locations.

The calibration of all newly purchased RAE Systems instruments should be tested by exposing the sensor(s) to known concentration calibration gas before the instrument is put into service.

For maximum safety, the accuracy of the MiniRAE 2000 should be checked by exposing it to a known concentration calibration gas before each day's use.

AVERTISSEMENTS

DANGER RISQUE D'ORIGINE ELECTROSTATIQUE:
Nettoyer uniquement avec un chiffon humide.

Pour des raisons de sécurité, cet équipement doit être utilisé, entretenu et réparé uniquement par un personnel qualifié. Étudier le manuel d'instructions en entier avant d'utiliser, d'entretenir ou de réparer l'équipement.

Utiliser seulement l'ensemble de batterie RAE Systems, la référence 012-3050, 012-3051 au 012-3052. Cet instrument n'a pas été essayé dans une atmosphère de gaz/air explosive ayant une concentration d'oxygène plus élevée que 21%. La substitution de composants peut compromettre la sécurité intrinsèque. Ne charger les batteries que dans emplacements désignés non-dangereuse.

La calibration de toute instruments de RAE Systems doivent être testé en exposant l'instrument a une concentration de gaz connue par une procédure diétalonnage avant de mettre en service l'instrument pour la première fois.

Pour une securite maximale, la sensibilité du MiniRAE 2000 doit être verifier en exposant l'instrument a une concentration de gaz connue par une procédure diétalonnage avant chaque utilisation journalière.

1. GENERAL INFORMATION

MiniRAE 2000 Portable VOC Monitor (Model PGM 7600) is a compact monitor designed as a broadband VOC gas monitor and datalogger for work in hazardous environments. It monitors Volatile Organic Compounds (VOC) using a Photo-Ionization Detector (PID) with a 9.8 eV, 10.6 eV, or 11.7 eV gas discharge lamp. Features are:

- **Lightweight and Compact**
 - Compact, light weight (19 oz.) and rugged design
 - Built-in sample draw pump
- **Dependable and Accurate**
 - Up to 10 hours of continuous monitoring with rechargeable battery pack
 - Designed to continuously monitor VOC vapor at ppm levels
- **User Friendly**
 - Preset alarm thresholds for STEL, TWA, low and high level peak values. Audio buzzer and flashing LED display are activated when the limits are exceeded.
- **Datalogging Capabilities**
 - 15,000 point datalogging storage capacity for data download to PC


MiniRAE 2000 consists of a PID with associated microcomputer and electronic circuit. The unit is housed in a rugged ABS + PC case with a backlit 1 line by 8 character dot matrix LCD and 3 keys to provide easy user interface.

1.1 General Specifications

Table 1.1

Portable VOC Monitor Specification	
Size:	8.2"L x 3.0"W x 2.0"H
Weight:	19.5 oz with battery pack
Detector:	Photo-ionization sensor with 9.8, 10.6, or 11.7 eV UV lamp
Battery:	A 4.8V /1250 mAH Rechargeable Nickel Metal Hydride battery pack (snap in, field replaceable)
Battery Charging:	10 hours charge through built-in charger
Operating Hours:	Up to 10 hours continuous operation
Display:	1 line by 8 characters 5x7 dot matrix LCD (0.4" character height) with LED back light automatically in dim light
Range, Resolution & Response time (t ₉₀):	
Isobutylene (calibration gas)	
	0-99 ppm 0.1 ppm 2 sec
	100-1,999 ppm 1.0 ppm 2 sec
	2000-10,000 ppm 1.0 ppm 2 sec
Measurement Accuracy (Isobutylene):	
	0 – 2000 ppm: ± 2 ppm or 10% of reading.
	> 2000 ppm: ± 20% of reading
PID Detector:	Easy access to lamp and sensor for cleaning and replacement
Correction Factors:	Built-in 102 VOC gases
Calibration:	Two-point field calibration of zero and standard reference gas
Calibration Memory:	
	Store up to 8 separate calibration, alarm limits and span value
Inlet Probe:	Flexible 5" tubing
Keypad:	1 operation key and 2 programming keys

GENERAL INFORMATION

Direct Readout:	Instantaneous, average, STEL and peak value, battery voltage and elapsed time
Intrinsic Safety:	UL & cUL Class 1, Division I, Group A,B,C,D, Temperature Code T3C (US & Canada); CE 0575  II 1G DEMKO 02 ATEX 0204759 Eex ia IIC T4 (Europe)
EM Interference:	No effect when exposed to 0.43 W/cm ² RF interference (5 watt transmitter at 12 inches)
Alarm Setting:	Separate alarm limit settings for Low, High, STEL and TWA alarm
Operating Mode:	Survey or Hygiene mode
Alarm:	90 dB buzzer and flashing red LEDs to indicate exceeded preset limits, low battery voltage, or sensor failure.
External Alarm:	Optional plug-in pen-size vibration alarm or remote alarm
Alarm Mode:	Latching or automatic reset
Real-time Clock:	Automatic date and time stamps on data logged information
Datalogging:	15,000 points with time stamp, serial number, user ID, site ID, etc.
Communication:	Upload data to PC and download instrument setup from PC through RS-232 port
Sampling Pump:	Internally integrated. Flow rate: 450-550 cc/min.
Temperature:	0° to 45°C (32° to 113°F)
Humidity:	0 % to 95 % relative humidity (non-condensing)
Housing:	ABS + PC, conductive coating, splash and dust proof, will withstand 1 meter drop test with rubber boot
Attachment:	Wrist strap, rubber boot and belt clip

2. OPERATION OF MINIRAE 2000

The MiniRAE 2000 Portable VOC Monitor is a compact Monitor designed as a broadband VOC gas monitor and datalogger for work in hazardous environments. It gives real time measurements and activates alarm signals whenever the exposure exceeds preset limits. Prior to factory shipment the MiniRAE 2000 is preset with default alarm limits and the sensor is pre-calibrated with standard calibration gas. However, the user should test the instrument and verify the calibration before the first use. After the monitor is fully charged and calibrated, it is ready for immediate operation.

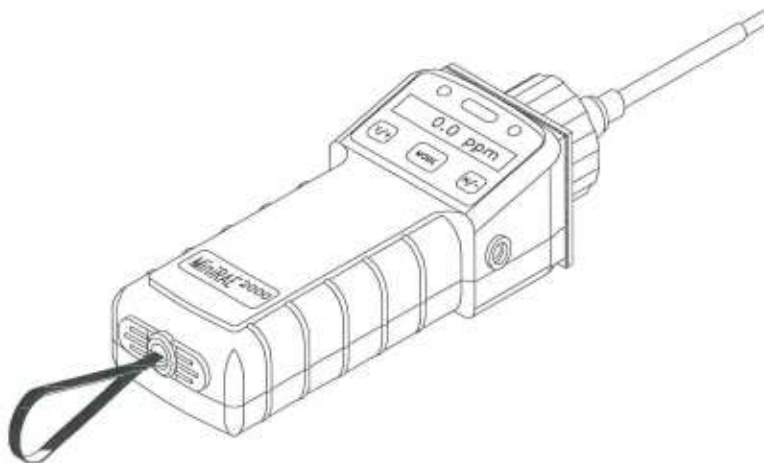


Figure 2-1 MiniRAE 2000

2.1 Physical Description

The main components of the MiniRAE 2000 Portable VOC monitor include:

- Three keys for user to interact with the monitor: 1 operation key and 2 programming keys for normal operation or programming of the monitor
- LCD display with back light for direct readout and calculated measurements
- Buzzer and red LED's for alarm signaling whenever the exposures exceed preset limits
- Wrist strap
- Charge contact for plugging directly to the charging station
- Gas entry and exit ports
- Serial communication port for PC interface
- External alarm and analog output port
- Protective rubber cover

2.2 Keys and Display

Figure 2.2 shows the LCD display and the keypad on the front panel of the monitor. The function of the 3 keys during normal operation are summarized below:

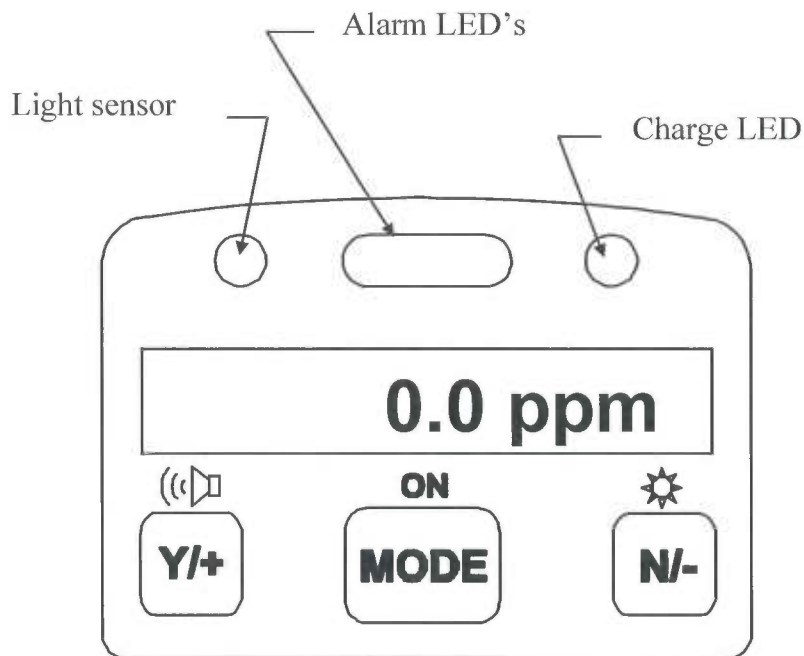


Figure 2-2 LCD Display and Keypad

Key Function in Normal Operation

[MODE] -Turn on/off the power* and step through menu items

[N/-] -Toggle on/off the back light, negative acknowledge, decrease value

[Y/+] -Start measurement, positive acknowledge, increase value

* Pressing and holding **[MODE]** key for 5 seconds turns off the power to the monitor. Monitor will beep once per second and display countdown timer during power-down sequence. Press **[MODE]** key momentarily to step through menu items. To save time, press any key during message scrolling to skip to the end of the message.

2.3 Power On/Off

To turn on the MiniRAE 2000 portable VOC monitor, press **[MODE]** key for one second and release. The audio buzzer will beep once and the air pump will turn on. The display will show “ON!..” and then “Ver n.nn” to indicate the unit’s current firmware version number. Next displayed are the serial number, the model number, Operating mode, current date and time, unit internal temperature, gas selected, high low, STEL, TWA/AVG alarm limits, battery voltage, and shut off voltage. Also displayed are internal mode settings such as User mode, Alarm mode, datalog time remaining and log periods in the respective order.

To turn off the MiniRAE 2000 portable VOC monitor, press and hold the **[MODE]** key for 5 seconds. The monitor will beep once per second during the power-down sequence with a count down timer showing the number of remaining seconds. The message “Off!..” flashes on the LCD display and the display will go blank indicating that the monitor is turned off.

Data protection during power off

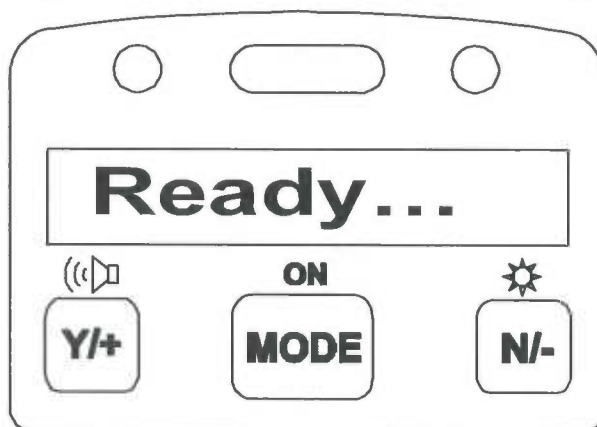
When the monitor is turned off, all the current real time data including last measured value are erased. However, the datalog data is preserved in non-volatile memory. Even if the battery is disconnected, the datalog data will not be lost. While the power is off, the real time clock will continue to operate until the battery is completely drained (usually in 4-5 days without any charging). If the battery is completely drained or is disconnected from the monitor for more than 30 minutes, the real time clock will be lost. In this case, the user needs to enter the real time clock information again, as described in Section 4, or send the PC clock during configuration through the PC communication.

2.4 Operation

The **MiniRAE 2000** VOC monitor has two operation modes: **Survey** and **Hygiene** mode. The **Survey mode** allows the user to manually start and stop the monitoring/measuring operation and display certain exposure values. In the **Hygiene mode**, the monitor runs continuously after the monitor is turned on. Refer to Section 4.7.1 for switching between the two modes.

2.4.1 Survey Mode

After the monitor is turned on, it runs through the start up menu. Then the message “**Ready...**” is displayed (see figure below).



At this point, the user has two options:

1. Step through the Main Menu.
2. Take a measurement.

Press the [MODE] button to step through the Main Menu. Press the [Y/+] button to proceed to take a measurement.

The Main Menu

Press the [MODE] button to enter the Main Menu. Press the [Y/+], [MODE] or [N/-] as indicated in the flow chart below to step through the Main Menu. The PID sensor and pump are turned off during this time.

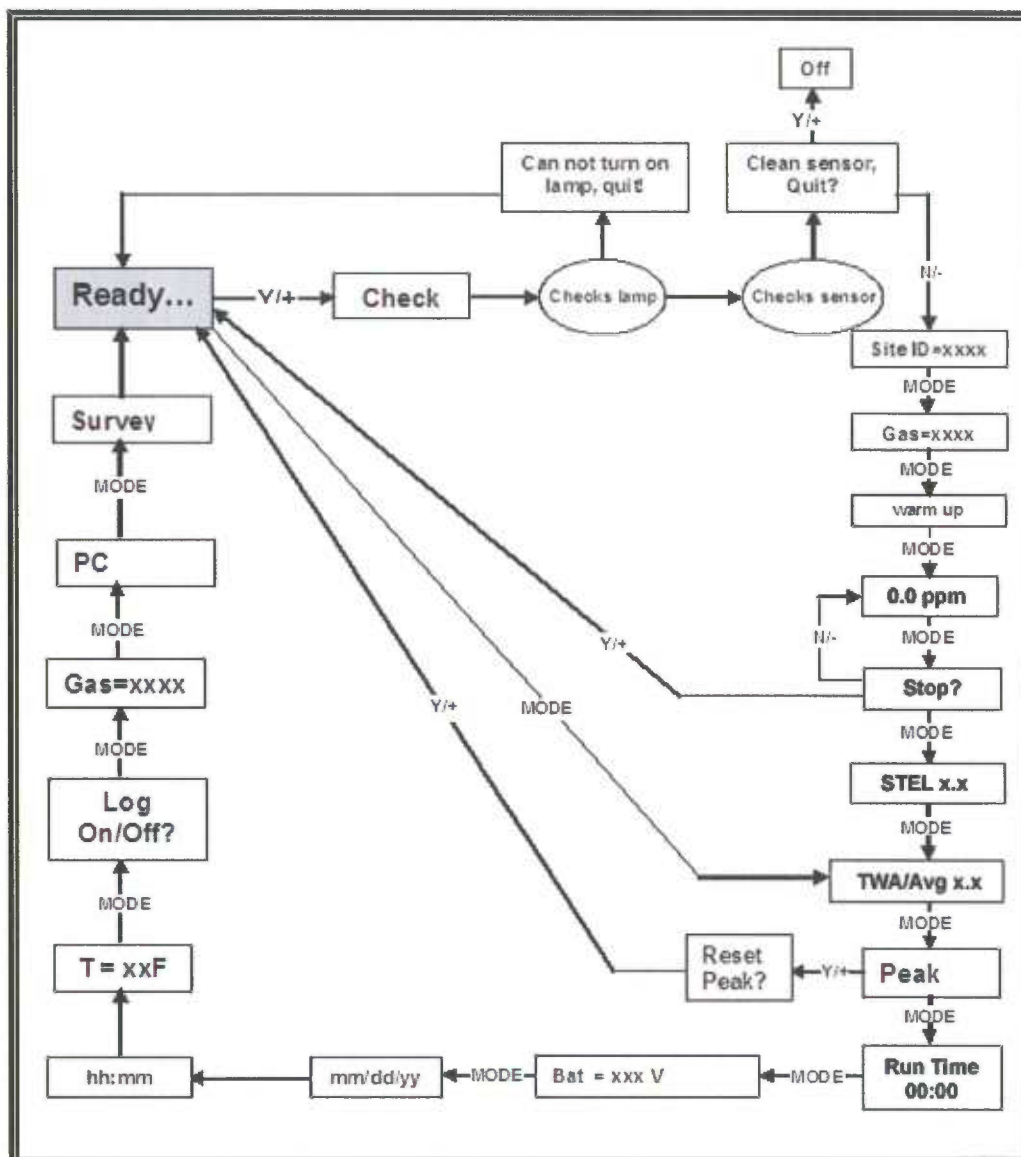
The Main Menu functions are:

- **Ready...**
- **Check**
- **Site ID = xxxx**
- **Gas = xxxx**
- **Warm up**
- **X.x ppm**
- **Stop?**
- **TWA/Avg x.x ppm**
- **STEL x.x ppm**
- **Peak x.x ppm**
- **Run time hh:mm**
- **Bat = X.XV**
- **Mm/dd/yy**
- **hh:mm**
- **T = xxxF [date, time and temperature (°C or °F)]**
- **Log On/Off?**
- **PC Comm?**
- **Survey**

OPERATION

These functions are arranged in a “round robin” order. To select a specific function, press the button as shown below until the desired function appears.

Main Menu



The Main Menu Functions

- **Ready...:** Indicates that the monitor is ready to take a measurement or to step through the Main Menu. Press the [Y/+] button to advance to taking a measurement (read “Taking a Measurement” on Page 2-12 for details).

Note: The **Ready...** screen is skipped if the menu is cycled through while a measurement is running.

- **Check...:** This message displays while the system is checking the lamp and the sensor. If the lamp test succeeds, the system will progress to checking the sensor. If the lamp test does not succeed, the display will read **Can not turn on lamp, quit!**
 - **Can not turn on lamp, quit!:** This message displays when the lamp does not turn on. The system will automatically return to **Ready...** allowing the user to test the lamp again. If the lamp fails a second time, turn the monitor off and refer to Section 7.2 “**PID Sensor & Lamp Cleaning / Replacement**”.
 - **Clean Sensor, Quit?:** This message displays when the sensor requires cleaning. Press the [Y/+] button to turn the monitor off and clean the sensor. Press the [N/-] button and the system will progress to the **Site ID = xx**
- **Site ID = xxxx:** This display shows the Site ID and indicates that the monitor is about to start taking measurements (read “Taking a Measurement” for details)

Note: This display appears only after a measurement has been started. It does not appear when the user is cycling through the Main Menu and the monitor is idling.
- **Gas = xxxx:** This display identifies the gas to be measured and indicates that the monitor is about to take a measurement (read “Taking a Measurement” for details)

OPERATION

Note: This display appears only after a measurement has been started. It does not appear when the user is cycling through the Main Menu and the monitor is idling.

- **x.x ppm:** (read “Taking a Measurement” for details)

Note: This display appears only after a measurement has been started. It does not appear when the user is cycling through the Main Menu and the monitor is idling.

- **TWA/Avg:** Displays (in ppm) the Time Weighted Average (TWA) or the Average since the start of the measurement. The average is recalculated every minute.
- **STEL:** Displays the Short Term Exposure Limit.
- **PEAK:** Displays (in ppm) the highest instantaneous reading since the start of the measurement. If [Y/+] is pressed while the peak reading is displayed, the unit will ask **Reset Peak?**. If [Y/+] is pressed again, the peak value will be cleared and the display will return to the **Ready...** message or instantaneous reading. The peak reading is automatically reset when a new measurement is started by pressing [Y/+] from the **Ready...** screen.
- **Run time hh:mm:** The duration of the current measurement period.
- **Bat = X.XV:** The current battery voltage.

Note: A fully charged battery pack should show 4.8 volts or higher. When the battery voltage falls below 4.4 volts, a flashing “Bat” will appear as a warning message. At that point, you have 20-30 minutes of run time remaining. When the battery voltage falls below 4.2 volts the monitor turns off automatically.
- **Mm/dd/yy:** The current date.
- **hh:mm:** The current time (24-hour format)

- **T = xxxF:** The internal unit temperature in degrees Fahrenheit. (see Section 4.7.13 to change temperature units)
- **Log on/Off?:** Allows the user to start datalogging of the current measurement. A superscript “L” flashes in the ppm measurement display when datalogging is on. This screen is not shown when datalogging is disabled or when the monitor is not operating in manual start/stop mode.
- **PC Comm?:** This function enables the user to upload data from the MiniRAE 2000 to a Personal Computer (PC) or send/receive configuration information between a PC and the MiniRAE 2000. Press **[MODE]** to return to **Ready... .**

To communicate with a PC, connect the monitor to the serial port of a PC and start the MiniRAE 2000 application software. Press the **[Y/+]** button and the LCD displays “**pause monitor, ok?**” Press the **[Y/+]** button one more time, and the display shows “**Comm...**” The monitor is now ready to receive commands from the PC.

- **Survey:** This function displays the Current Operating Mode (**Survey** or **Hygiene**).

Taking a Measurement

There are two ways to start a measurement.

1. Operating in Hygiene mode.
2. Manually start and stop measurement in Survey mode.

To start a measurement in Hygiene mode, please refer to Section 4.7.1, “**Change Operation Mode**”. To start a measurement in Survey Mode, the MiniRAE 2000 monitor must first be in the “Ready...” mode. This is the mode to which the monitor normally powers up.

Measurement phases

1. Ready
2. Start measurement
3. Measurement display and datalogging
4. Stop measurement

Ready

The display reads **Ready...** indicating the unit is ready to start a measurement.

Start Measurement

Press the [Y/+] button to start the check cycle (see above), and then the measurement cycle.

After completing the **Check** cycle, the display will show the **Site ID** and then the **Gas** selected for measurement. The pump will start and the reading will be displayed. The **Peak** and **Average** values will be automatically reset to zero.

Measurement Display and Datalog

Instantaneous readings of the gas concentration in parts per million (ppm) are updated every second. A flashing superscript **L** is displayed when datalogging is on. Datalog information is saved only after one full datalog period is completed.

Stop Measurement

Press the **[MODE]** button and the display shows Stop? Press **[N/-]** to continue measurement and **[Y/+]** to stop the measurement and datalog event. The pump stops automatically when measurement is stopped. Peak and average values for the current measurement can be read in idle mode until a new measurement is started.

Automatic Increment of Site ID

Every time a measurement is taken, the site ID will be incremented by one automatically in Survey mode.

Variable Alarm Signal

In Survey Mode, if the measurement exceeds the low alarm limit, the buzzer and flashing alarm are activated and will beep/flash once per second. The alarms will increase in frequency as the gas concentration approaches the high alarm limit reaching 8 times per second when the high alarm has been exceeded.

Press **[Y/+]** key to clear if latching alarm.

2.4.2 Hygiene Mode

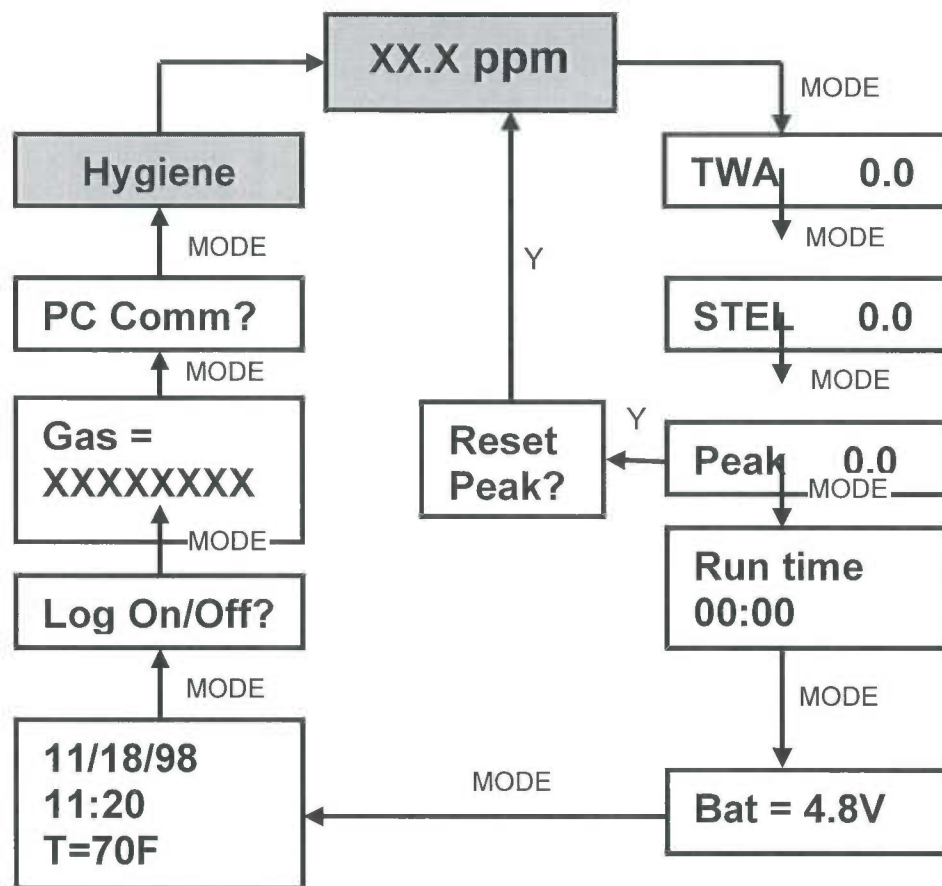
In Hygiene Mode, the unit will continuously taking measurements, once the power is turned on. After the initial start-up sequence displaying the current monitor settings, the LCD displays the instantaneous readings.

The Hygiene operation menu displays include:

- **Real time readings in ppm**
- **Current TWA/Avg, STEL and Peak values (see Section 4.6.6)**
- **Run time**
- **Current battery voltage**
- **Date, time and temperature**
- **Log on/off?**
- **Gas name**
- **PC communication?**
- **Hygiene**

Detailed description of most of these displays are the same as Section 2.4.1.

HYGIENE MODE MAIN MENU



To choose a specific display, press the [MODE] key one or more times until the desired display appears, or the [Y/+] key where indicated with a Y.

Note: To get back to instantaneous reading from any of the above display, press [MODE] key repeatedly until the “XX.X ppm” display appears.

2.5 Alarm Signals

During each measurement period, the gas concentration is compared with the programmed alarm limits (gas concentration alarm limit settings: Low, High, TWA and STEL). If the concentration exceeds any of the preset limits, the loud buzzer and red flashing LED are activated immediately to warn the user of the alarm condition.

In addition, the MiniRAE 2000 will alarm if one of the following conditions occurs: battery voltage falls below a pre-set voltage level (4.4 V), failure of UV lamp, pump stall, or when the datalog memory is full. When the low battery alarm occurs, there will be approximately 20-30 minutes of operating time remaining. When the battery voltage falls below 4.2 V, the monitor will turn off automatically.

OPERATION

Alarm Signal Summary:

Condition	Alarm Signal
Gas exceeds "High Alarm" limit	3 beeps/flushes per second
Gas exceeds "Low Alarm" limit	2 beeps/flushes per second
Gas exceeds "TWA" limit	1 Beeps/flushes per seconds
Gas exceeds "STEL" limit	1 Beeps/flushes per seconds
Pump failure	3 beeps/flushes per second plus "Pump" message on LCD
PID lamp failure	3 beeps/flushes per second plus "Lamp" message on LCD
Low battery	1 flash per second, 1 beep per minute plus "Bat" message on LCD
Memory full	1 flash per second plus "Mem" message on LCD

Alarm Signal Testing:

Under normal non-alarm conditions, it is possible to test the MiniRAE 2000 LED and buzzer in Special Diagnostic Mode (see Section 8 for details).

2.6 Preset Alarm Limits and Calibration

The MiniRAE 2000 portable VOC monitor is factory calibrated with standard calibration gas, and is programmed with default alarm limits. There are 102 gas settings stored in the library. Some examples of calibration and alarm limits are shown below. Refer to Section 4 on programming procedures for selecting a different gas, perform a calibration or set new alarm limits.

Factory Calibration and Preset Alarm Limits

Cal Gas	Cal Span	unit	Low	High	TWA	STEL
Isobutylene	100	ppm	50	100	100	250
Hexane, n-	100	ppm	500	750	500	750
Xylene, m-	100	ppm	100	150	100	150
Benzene	5	ppm	2	5	5	2
Styrene	50	ppm	20	40	20	40
Toluene	100	ppm	50	100	50	100
Vinyl Chloride	10	ppm	5	10	5	10
Custom	100	ppm	50	100	50	100

2.7 Integrated Sampling Pump

The MiniRAE 2000 portable VOC monitor includes an integrated sampling pump. This is a diaphragm type pump that provides a 500-600 cc per minute flow rate. Connecting a Teflon or metal tubing with 1/8 inch inside diameter to the gas inlet port of the MiniRAE 2000, this pump can pull in air samples from 200 feet away horizontally, or 90 feet vertically, at about 3 feet per second flow speed.

The pump turns on when a measurement is started, and turns off when the sample is manually stopped in Survey mode or when the unit is turned off from Hygiene Mode.

If liquid or other objects are pulled into the inlet port filter, the monitor will detect the obstruction and shut down the pump immediately. The alarm will be activated and a flashing error message "Pump" will be also displayed on the LCD display.

The user should acknowledge the pump shut off condition by clearing the obstruction and pressing the [Y/+] key to re-start the pump.

The pump stall threshold is set in the special Diagnostic Mode (Section 8).

2.8 Back Light

The LCD display is equipped with an LED back light to assist in reading the display under poor lighting conditions. Pressing and holding the [N/-] key for one second in normal operation can turn on the backlight. The backlight can be turned off by pressing [N/-] a second time. If the [N/-] key is not pressed, the back light will be turned off automatically after a pre-programmed time-out period to save power.

In addition, the ambient light is sensed and the back light will be turned on automatically if the ambient light is below a threshold level. The back light is turned off automatically when the ambient light exceeds the threshold level.

See Section 8 for instructions on how to set the light threshold level.

Note: The LED backlight consumes about 20-30% of the total average current, when the instrument is idle or not taking a measurement.

2.9 Datalogging

During datalogging, the MiniRAE 2000 Portable VOC monitor flashes a superscript “L”, on the display to indicate that datalogging is enabled. The monitor stores the time stamp, sample number, and measured gas concentration at the end of every sample period (when data logging is enabled). In addition, the following information are stored: user ID, site ID, serial number, last calibration date, and alarm limits. All data are retained (even after the unit is turned off) in non-volatile memory so that it can be down loaded at a later time to a PC.

Datalogging event

When Datalogging is enabled, measurement readings are being saved. These data are stored in “groups” or “events. A new event is created and stored each time the monitor is turned on, or a configuration parameter is changed, or datalogging is interrupted (e.g. Communication with PC during Hygiene mode). Information, such as start time, user ID, site ID, gas name, serial number, last calibration date, and alarm limits will be recorded.

Datalogging sample

After an event is recorded, the unit records a shorter form of the data. This data contains: the sample number, time (hour/minute) and gas concentration.

3. OPERATION OF ACCESSORIES

The accessories for the MiniRAE 2000 include:

- An AC Adapter (Battery Charger)
- Alkaline battery holder
- Water Trap Filter

Optional Accessories:

- Dilution Fitting
- Calibration adapter
- Calibration regulator and Flow controller
- Organic Vapor Zeroing kit

3.1 Standard Kit and Accessories

1) AC Adapter (Battery Charger)

WARNING

To reduce the risk of ignition of hazardous atmospheres, recharge battery only in area known to be non-hazardous. Remove and replace battery only in area known to be non-hazardous.

Ne charger les batteries que dans emplacements designés non-dangereuses.

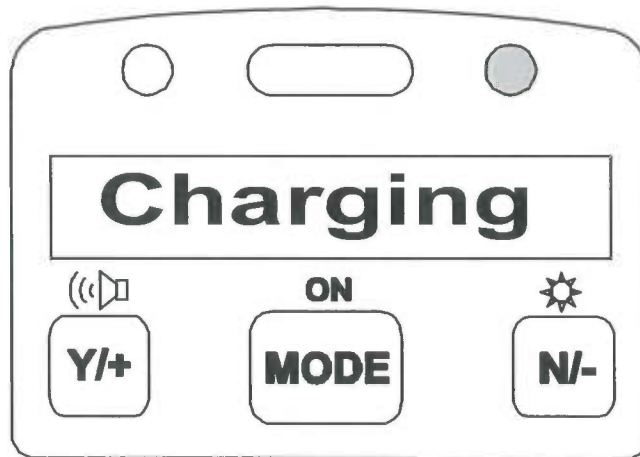
A **battery charging circuit** is built into the MiniRAE 2000 monitor. It only needs a regular AC to 12 V DC adapter (wall mount transformer) to charge the monitor.

To charge the battery inside the MiniRAE 2000 monitor:

1. Power off the Monitor.
2. Connect the AC adapter (or the optional automotive charging adapter) to the DC jack on the MiniRAE 2000 monitor. If the unit was off, it will automatically turn on.
3. The first message displayed will be "Deep discharge?" The unit will ask this question for three times. If the user wants to discharge the battery pack, affirm this query with the [Y/+] key, otherwise the unit will move on to the charge mode directly.

OPERATION OF ACCESSORIES

4. While charging, the display message will alternate between “Charging” and “Bat=x.xV” (x.x is the present battery voltage). The LED should be red in color when charging.



5. When the battery is fully charged, the LED will change from red to green and the message “Fully charged” will appear on the display. After the battery is fully charged, the unit will enter the “trickle charge” mode. In which, the red LED will turn on for several seconds every minute, to maintain the full charge.

A completely discharged MiniRAE 2000 monitor will be charged to full capacity within 10 hours. The battery will be drained slowly even if the monitor is turned off. If the monitor has not been charged for 7-10 days, the battery voltage will be low.

The factory-supplied battery is designed to last for 10 hours of normal operation (no alarm, no back light condition), for a new battery under the best condition. As the battery becomes older or is subject to adverse conditions (such as cold ambient temperature), the battery capacity will be reduced significantly.

2) Alkaline Battery Holder

An alkaline battery holder is supplied with each MiniRAE 2000. It accepts four AA size alkaline batteries and can be used in place of the Ni-MH or Ni-Cd battery pack to provide approximately 12-14 hours of operation. The adapter is intended to be used in emergency situations when there is no time to charge the Ni-Cd or Ni-MH battery pack.

To install the adapter, remove the cover of the battery compartment. Remove the Ni-Cd or Ni-MH battery pack from the battery compartment and replace with the alkaline battery adapter. Replace the battery compartment cover.

The internal charging circuit is designed to prevent damage to alkaline batteries and the charging circuit when alkaline batteries are installed inside the monitor.

Note: The AA Alkaline battery adapter supplied by RAE Systems Inc. is intrinsically safe!

3) Water Trap Filter

The water trap filter is made of PTFE (Teflon[®]) membrane with a 0.45 micron pore size to prevent water from being sucked into the sensor manifold, which would cause extensive damage to the monitor. It will also remove any dust and other particles from entering the monitor and prolong the operating life of the sensor. To install the water trap, simply insert it to the front of the inlet tube of the MiniRAE 2000 monitor.

3.2 Optional Accessories

1) Dilution Fitting

The user may wish to install a dilution fitting on the inlet to dilute the gas samples. One application for a dilution fitting is to measure organic gas when the concentration exceeds the upper limit of the sensor range.

Make sure to set the dilution ratio in the programming mode (see Section 4.7.9) so that the correct gas reading will be displayed when the dilution fitting is used.

WARNING: To use a dilution fitting, the user must have the monitor located in a clean atmosphere outside the confined space and use a remote access probe or Tygon tubing to measure the gas concentration inside the confined space.

2) Calibration Adapter

The calibration adapter for the MiniRAE 2000 is a simple 6-inch Tygon tubing with a metal adapter on one end. During calibration, simply insert the metal adapter into the regular gas inlet probe of the MiniRAE 2000 and the tubing to the gas regulator on the gas bottle.

3) Calibration Regulator and Flow Controller

The Calibration Regulator and Flow controller is used in the calibration process. It regulates the gas flow rate from the Span gas cylinder into the gas inlet of the MiniRAE 2000 monitor during calibration process. The maximum flow rate allowed by the flow controller is about 0.5L/min (500 cc per min.). Alternatively, a Demand-flow Regulator or a Tedlar gas bag may be used to match the pump flow precisely.

4) Organic Vapor Zeroing kit (Charcoal filter)

The Organic Vapor Zeroing Kit is used for filtering organic air contaminants that may affect the zero calibration reading. To use the Organic Vapor Zeroing Kit, simply connect the filter to the inlet port of the MiniRAE 2000.

4. PROGRAMMING OF MINIRAE 2000

The MiniRAE 2000 Monitor is built with a microcomputer to provide programming flexibility. Authorized users can recalibrate the monitor, change the alarm limits, change site ID, user ID, lamp type, and real time clock, etc.

Programming is menu-driven to provide intuitive end-user operation. The display shows the menu options and the key pad used for menu selection and data entry.

4.1 Programming Mode

The programming mode allows the users to change the setups in the monitor, calibrate the monitor, modify the sensor configuration and enter user information, etc. The programming mode has four menu items. Each menu item includes several sub-menus to perform additional programming functions. Appendix A shows a more detailed menu tree structure.

Programming Menu

- Calibrate/Select Gas?

- Change Alarm Limits?

- Change Datalog?

- Change Monitor Setup?

Once inside the programming mode, the LCD will display the first menu. Each subsequent menu item can be viewed by pressing the [N/-] repeatedly until the desired menu is displayed. To enter the sub-menu of a particular menu, press [Y/+] key, the sub-menu will be displayed.

Return to Operation mode: To exit the programming mode and return to operation, press the [MODE] key once at any of the programming menu displays.

4.2 Keys for Programming Mode

The three keys perform a different set of functions during the programming mode as summarized below.

Key	Function in Programming Mode
[MODE]:	Exit menu when pressed momentarily or exit data entry mode when pressed and held for 1 second
[Y/+]:	Increase alphanumerical value for data entry or confirm (yes) for a question
[N/-]:	Decrease alphanumerical value for data entry or deny (no) for a question

4.3 Entering into Programming Mode

1. Turn on the MiniRAE 2000 monitor and wait for the **“Ready..”** message or the instantaneous reading display **“0.0 ppm”** message displayed.
2. Press and hold down both **[N/-]** and **[MODE]** keys for three seconds to enter programming mode. This delay is to prevent the user from entering programming mode by accident.
3. The first menu item **“Calibrate/select Gas?”** will be displayed.
4. Release both **[MODE]** and **[N/-]** keys simultaneously to start the programming mode
5. Press **[N/-]** key to scroll to the next menu item of the programming menu. Press **[Y/+]** key to select the displayed menu item.

The following Sections 4.4 - 4.7 describe the details of each menu options.

4.4 Calibrate and Select Gas

WARNINGS

The calibration of all newly purchased RAE Systems instruments should be tested by exposing the sensor(s) to known concentration calibration gas before the instrument is put into service for the first time.

For maximum safety, the accuracy of the MiniRAE 2000 should be checked by exposing it to known concentration calibration gas before each day's use.

In the first menu of the programming mode, the user can perform functions such as calibration of the MiniRAE 2000 Monitor, select default cal memories, and modify cal memories (see Table 4.4).

Table 4.4

Calibrate/Select Gas Sub-Menu
Fresh Air Cal?
Span Cal?
Select Cal Memory?
Change Span Value?
Modify Cal Memory?
Change Correction Factor?

Calibrating the MiniRAE 2000 monitor is a two-point process using “fresh air “ and the standard reference gas (also known as span gas). First a “Fresh air” calibration, which contains no detectable VOC (0.0 ppm), is used to set the zero point for the sensor. Then a standard reference gas that contains a known concentration of a given gas is used to set the second point of reference.

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Note: The span value must be set prior to calibrating for fresh air or span.

The user can store calibrations for up to 8 different measurement gases. The default gas selections are as follows:

Cal Memory #0.....Isobutylene

Cal Memory #1.....Hexane

Cal Memory #2.....Xylene

Cal Memory #3.....Benzene

Cal Memory #4.....Styrene

Cal Memory #5.....Toluene

Cal Memory #6.....Vinyl Chloride

Cal Memory #7.....Custom?

Memory #0 functions differently than the other 7 memories. For Memory #0, isobutylene is always the calibration gas. When the gas is changed in Memory #0 to one of 100 other preprogrammed chemicals or to a user-defined custom gas, a correction factor is applied to all the readings. During calibration, the unit requests isobutylene gas and displays the isobutylene concentration immediately following calibration, but when the unit is returned to the normal reading mode, it displays the selected gas and applies the correction factor.

The other 7 cal memories require the same calibration gas as the measurement gas. These memories may also be modified to a preprogrammed chemical or to a user-defined custom gas. In the gas library, only the gases that can be detected by the installed UV lamp will actually be displayed. Note that although the correction factor for the new gas will be displayed and can be modified, this factor is not applied when Memories #1-7 are

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used. Therefore the factor will not affect the readings in these memories.

Once each of the memories has been calibrated, the user can switch between the calibrated gases by changing the cal memory without the need to recalibrate. Or the user can switch the measurement gas in Memory #0 and the appropriate correction factor will automatically be applied without the need to recalibrate. If the gas is changed in Memories #1-7, it is necessary to recalibrate.

To change a default gas from the list above to a library or custom gas, first go to Select Cal Memory (Section 4.4.3) and then proceed to Modify Cal Memory (Section 4.4.5) to enter the desired gas. If the desired compound does not appear in the preprogrammed library, the user can use the Custom_VOC entry in the library, or the name and correction factor of any of the existing compounds can be changed as described in Section 4.4.5. A list of some 300 correction factors is given in Technical Note 106, available at the website www.raesystems.com.

4.4.1 Fresh Air Calibration

This procedure determines the zero point of the sensor calibration curve. To perform a fresh air calibration, use the calibration adapter to connect the MiniRAE 2000 to a “fresh” air source such as from a cylinder or Tedlar bag (option accessory). The “fresh” air is clean dry air without any organic impurities. If such an air cylinder is not available, any clean ambient air without detectable contaminant or a charcoal filter can be used.

1. The first sub-menu shows: “Fresh air Cal?”
2. Make sure that the MiniRAE 2000 is connected to one of the “fresh” air sources described above.
3. Press the [Y/+] key, the display shows “zero in progress” followed by “wait..” and a countdown timer.

After about 15 seconds pause, the display will show the message “update data...zeroed... reading = X.X ppm...” Press any key or wait about 20 seconds, the monitor will return back to “Fresh air Calibration?” submenu.

4.4.2 Span Calibration

This procedure determines the second point of the sensor calibration curve for the sensor. A cylinder of standard reference gas (span gas) fitted with a 500 cc/min. flow-limiting regulator or a flow-matching regulator is the simplest way to perform this procedure. Choose the 500 cc/min. regulator only if the flow rate matches or slightly exceeds the flow rate of the instrument pump. Alternatively, the span gas can first be filled into a Tedlar Bag, or delivered through a demand-flow regulator. Connect the calibration adapter to the inlet port of the MiniRAE 2000 Monitor, and connect the tubing to the regulator or Tedlar bag.

Another alternative is to use a regulator with >500 cc/min flow but allow the excess flow to escape through a T or an open tube. In the latter method, the span gas flows out through an open tube slightly wider than the probe, and the probe is inserted into the calibration tube.

Before executing a span calibration, make sure the span value has been set correctly (see next sub-menu).

1. Make sure the monitor is connected to one of the span gas sources described above.
2. Press the [Y/+] key at the "Span Cal?" to start the calibration. The display shows the gas name and the span value of the corresponding gas.
3. The display shows "Apply gas now!" Turn on the valve of the span gas supply.

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4. Display shows “wait... 30” with a count down timer showing the number of remaining seconds while the monitor performs the calibration.
5. To abort the calibration, press any key during the count down. The display shows “Aborted!” and return to “Span Cal?” sub-menu.
6. When the count down timer reaches 0, the display shows the calibrated value.
Note: The reading should be very close to the span gas value.
7. During calibration, the monitor waits for an increased signal before starting the countdown timer. If a minimal response is not obtained after 35 seconds, the monitor displays “No Gas!” Check the span gas valve is on and for lamp or sensor failure before trying again.
8. The calibration can be started manually by pressing any key while the “Apply gas now!” is displayed.
9. After a span calibration is completed, the display will show the message “Update Data Span Cal Done! Turn Off Gas.”
10. Turn off the flow of gas. Disconnect the calibration adapter or Tedlar bag from the MiniRAE 2000 Monitor.
11. Press any key and it returns back to “Span Gas Cal?”

4.4.3 Select Cal Memory

This function allows the user to select one of eight different memories for gas calibration and measurement. For Memories #1-7, the calibration and measurement gas is the same and no correction factor is applied. For Memory #0, the calibration gas is always isobutylene and the measurement gas may be different, in which case the correction factor for that gas is automatically applied. The default gas selections are listed in Section 4.4

1. "Select Cal Memory?" is the third sub-menu item in the Calibration sub-menu. Pressing the [Y/+] key, the display will show "Gas =" gas name followed by "Mem # x?"
2. Press [N/-] to scroll through all the memory numbers and the gas selections respectively. Press [Y/+] to accept the displayed Cal Memory number.
3. After the [Y/+] key is pressed, the display shows "Save?" Press [Y/+] key to save and proceed. Press [N/-] to discard the entry and advance to the next sub-menu.
4. If the gas in a newly selected Cal Memory number is not calibrated, the display shows "CF= x.xx". A correction factor with the value "x.xx" will be applied.
5. If the gas of a newly selected cal memory number has been calibrated previously, the display shows "Last calibrated xx/xx/xx".

4.4.4 Change Span Value

This function allows the user to change the span values of the calibration gases.

1. "Change Span Value?" is the fourth sub-menu item in the Calibration sub-menu
2. Press **[Y/+]**, display shows the gas name and the span value. A cursor will blink at the first digit of the Span value. To modify the span gas value, go to Step 3. Otherwise, press and hold the **[MODE]** key for 1 second to accept the previously stored span gas value and move to the next sub-menu.
3. Starting from the left-most digit of the span gas value, use the **[Y/+]** or **[N/-]** key to change the digit value and press **[MODE]** key momentarily to advance to next digit. Repeat this process until all digits are entered. Press and hold the **[MODE]** for 1 second to exit.
4. The display shows "Save?" To accept the new value, press the **[Y/+]** key. Press the **[N/-]** key or the **[MODE]** key to discard the change and move to the next sub-menu.

4.4.5 Modify Cal Memory

If the current cal memory number selected is not memory 0, users will be prompted whether to modify the settings of the selected cal memory. Press **[Y/+]** to modify the cal memory and **[N/-]** to go to the next sub-menu.

Once **[Y/+]** is pressed the LCD display will show the current memory number, current Gas selected and prompt user for acceptance of current gas selected.

1. Press **[N/-]** to modify the gas selection if desired. Or press **[Y/+]** key to skip the change of gas selection, and proceed to the next sub-menu.
2. After pressing **[N/-]**, display shows “Copy gas from library?” Press **[Y/+]** to accept or **[N/-]** for the next sub-menu, “Enter Custom gas?”
3. In the “Copy gas from library” submenu, use **[Y/+]** and **[N/-]** keys to scroll through the selections in the library. Press **[MODE]** key momentarily to select the gas. The display shows “Save?” Press **[Y/+]** to save or **[N/-]** to discard the changes and proceed to next sub-menu.
4. In the Custom gas sub-menu, the user can enter the gas name. Press the **[Y/+]** or **[N/-]** key to cycle through all 26 letters and 10 numerals. Press the **[MODE]** key momentarily to advance to the next digit. The flashing digit will move to the next digit to the right. Repeat this process until all digits (up to 8 digits) of the custom gas name is entered.

Press and hold the **[MODE]** key for 1 second to exit the name entry mode. The display will show “Save?” Press **[Y/+]** to save the entry, or **[N/-]** to discard the changes.

4.4.6 Change Correction Factor

This function allows the user to change the Correction Factor of the standard calibration gas (only for Cal Memory #0).

1. “Change Correction Factor?” is the sixth sub-menu in the Calibration sub-menu.
2. Press **[Y/+]** key. Display shows the gas name, then the correction factor.

A cursor blinks at the left-most digit of the correction factor. If user wants to modify the correction factor, go to Step 3. Otherwise, press and hold the **[MODE]** key for 1 second to accept the previously stored correction factor value and return to the first sub-menu of the calibrate/select gas menu.

3. Starting from the left-most digit of the correction factor, use **[Y/+]** or **[N/-]** key to change the digit value and press **[MODE]** key momentarily to advance to the next digit, the cursor will move to the next digit to the right. Repeat this process until all digits are entered. Press and hold the **[MODE]** for 1 second to exit.
4. The display shows “Save?” To confirm the new value, press **[Y/+]** to accept the change. Press **[N/-]** or **[MODE]** to discard the change and return to the first sub-menu, Calibrate and Select Gas.

4.5 Change Alarm Limits

In this menu, the user can change the high and low alarm limits, the STEL limit and the TWA limit (see Table 4.5 below). Press the [Y/+] key and the display shows the current gas selected followed by the first sub-menu item below.

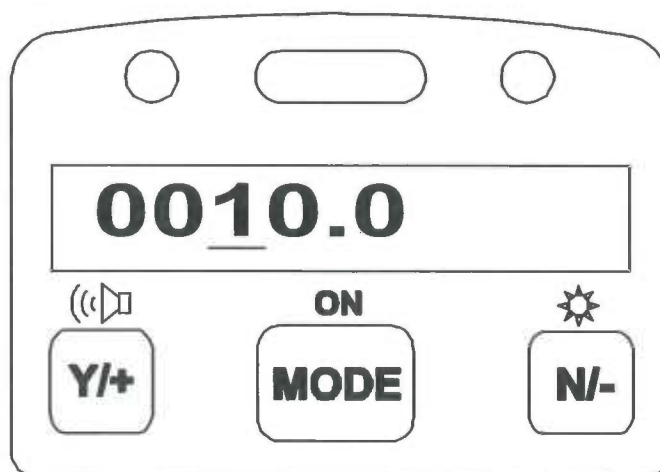
Table 4.5

Alarm Limit Sub-Menu
Change High Alarm limit?
Change Low Alarm limit?
Change STEL limit?
Change TWA limit?

1. Scroll through the Alarm Limit sub-menu using the [N/-] key until the display shows the desired limit to be changed, e.g., "High limit?", "STEL limit?", etc.

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2. Press the **[Y/+]** key to select the desired limit and the display shows a flashing cursor on the left-most digit of the previously stored alarm limit.



3. To modify this limit value, use the **[Y/+]** or **[N/-]** key to change the digit value and press the **[MODE]** key momentarily to advance to the next digit. The flashing digit will move to the next digit to its right. Repeat this process until the new limit value is entered. Press and hold the **[MODE]** key for 1 second to exit data entry mode.
4. If there is any change to the existing value, the display shows "Save?" Press **[Y/+]** to accept the new value and move to the next sub-menu. Press **[N/-]** to discard the changes and move to the next sub-menu.

4.5.1 Change Low Alarm Limit

The second sub-menu item in the Alarm Limit sub-menu allows the user to change the Low Alarm limit. The LCD displays “Low limit?” To change Low Alarm limit, press [Y/+] key, or Press [N/-] key advance to next sub-menu in Table 4.5.

1. Press [Y/+] and the display will show a flashing cursor on the left-most digit of the previously stored Low alarm limit.
2. To modify this limit value, use the [Y/+] or [N/-] key to change the digit value and press the [MODE] key momentarily to advance to the next digit. The flashing digit will move to the next digit to its right. Repeat this process until the new limit values is entered. Press and hold the [MODE] key for 1 second to exit data entry mode.
3. If there is any change to the existing value, the display shows “Save?” Press [Y/+] to accept the new value and move to the next sub-menu. Press [N/-] to discard the changes and move to the next sub-menu.

4.5.2 Change STEL Limit

This sub-menu item allows the user to change the STEL limit. The display shows “STEL limit?”

1. Press the [Y/+] key and the display will show a flashing cursor on the left-most digit of the previously stored STEL limit.
2. To modify this limit value, use the [Y/+] or [N/-] key to change the digit value and press the [MODE] key momentarily to advance to the next digit. The flashing digit will move on to next digit to its right. Repeat this process until the new limit values is entered. Press and hold the [MODE] key for 1 second to exit data entry mode.
3. If there is any change to the existing value, the display shows “Save?” Press [Y/+] to accept the new value and move to the next sub-menu. Press [N/-] to discard the changes and move to the next sub-menu.

4.5.3 Change TWA Limit

This sub-menu item allows the user to change the TWA limit. The LCD displays “TWA limit?”

1. Press [Y/+] and the display will show a flashing cursor on the left-most digit of the previously stored TWA limit.
2. To modify this limit value, use the [Y/+] or [N/-] key to change the digit value and press the [MODE] key momentarily to advance to the next digit. The flashing digit will move on to next digit to its right. Repeat this process until the new limit values is entered. Press and hold the [MODE] key for 1 second to exit data entry mode.
3. If there is any change to the existing value, the display shows “Save?” Press [Y/+] to accept the new value and move to the next sub-menu. Press [N/-] to discard the changes and move to the next sub-menu.

4.6 Change Datalog

The MiniRAE 2000 monitor calculates and stores the concentration and ID of each sample taken. In the datalog sub-menu, a user can perform the tasks and functions shown below.

Datalog Sub-Menu

Reset Peak/Minimum?

Clear Data?

Change Data Period?

Change Average Type?

4.6.1 Reset Peak

This function will reset the peak and minimum stored in the data memory. Note: this function will not clear the STEL or TWA data.

1. “Reset Peak?” is the first sub-menu item in the Datalog sub-menu (Table 4.6).
2. Press the [Y/+] key to reset the Peak/Minimum Values. The display shows “Are You Sure?”
3. Pressing the [Y/+] key again will reset the values. The display shows “Peak/Minimum Cleared” and moves to the next submenu.
4. Press the [N/-] or [MODE] key to exit without resetting the values and move to the next sub-menu.

4.6.2 Clear Data

This function will erase all data stored in the non-volatile datalog memory. Note: This function does not change STEL, TWA, Peak, Minimum and run time values, which are stored in the regular data memory.

1. "Clear Data?" is the third sub-menu item in the Datalog sub-menu.
2. Press the **[Y/+]** key to clear the datalog memory. The display shows "Are you sure?"
3. Press the **[Y/+]** key again to confirm erasure of all the datalog memory.
4. Press the **[N/-]** or **[MODE]** key to exit without clearing the datalog memory and move to the next datalog sub-menu.

4.6.3 Change Data Period

The datalog period can be programmed from 1 to 3,600 seconds (1 hour).

1. "Change Data Period?" is the fifth sub-menu item in the Datalog sub-menu.
2. Press the [Y/+] key and the display shows "Datalog Period = XXXX" with the left-most digit flashing, where "XXXX" is the previously stored data log period.
4. To modify this period, starting from the left-most digit, use the [Y/+] or [N/-] key to change the digit value and press the [MODE] key momentarily to advance to the next digit. The flashing digit will move to the next digit to the right. Repeat this process until all 4 digits of the new period are entered. Press and hold the [MODE] key for 1 second to exit data entry mode.
5. If there is any change to the existing value, the display will show "Save?" Press [Y/+] to accept the new value or [N/-] to discard the changes and move to the next sub-menu.

4.6.4 Change Average Type

The user can select either an 8-hour Time Weighted Average (TWA) or a running Average. The running average is simply the average of all instantaneous (1-second) readings since the measurement was started. This average may increase or decrease with time depending on the readings. The TWA is a cumulative value used to estimate the fraction of the 8-hour limit to which the user has been exposed since the start of the measurement. This value can only increase or remain constant, never decrease. Refer to Technical Note 119 for more information on how TWA is calculated.

1. “Change Average Type?” is the sixth sub-menu in the Datalog sub-menu.
2. Press the [Y/+] key to enter the function.
3. The display will show “Running Average?” or “Time Weighted Average?” depending on the current average type.
4. Press [N/-] key to toggle between the average types. Press [Y/+] key to select the displayed average type.
5. If there is any change to the existing setting, the display shows “Save?” Press [Y/+] to save the change. Press [N/-] or [MODE] to discard the change and return to the first sub-menu.

4.7 Change Monitor Setup

Several monitor specific variables can be changed in this menu. The following is a list of configuration data that can be modified by the user.

Monitor Setup Sub-Menu	Diagnostic Mode
Change Operation Mode?	“
Change Site ID?	Change Unit ID?
Change User ID?	Change Host ID?
Change Alarm Mode?	“
Change User Mode?	“
Change Date?	“
Change Time?	“
Change Lamp?	“
Change Pump Duty Cycle?	“
Change Unit?	“
Change Dilution Ratio?	“
Change Output?	“
Change DAC Range?	“
Set Temperature Unit?	“

4.7.1 Change Operation Mode

MiniRAE 2000 supports two operation modes: Survey and Hygiene mode.

Survey mode: Manual start/stop of measurements and display of certain exposure values.

Hygiene mode: Automatic measurements, running and datalogging continuously and calculates additional exposure values.

1. “Change Op Mode?” is the first sub-menu item in the Monitor Setup menu (Table 4.7).
2. Press the [Y/+] key and the display shows the current user mode: “Op Mode = *current mode*?”
3. Press the [Y/+] key to accept the currently displayed operation (Op) mode. Press [N/-] to toggle to the other operation mode. Press [MODE] to exit this sub-menu and move to the next monitor setup sub-menu.
4. When changing Op mode from Hygiene to Survey, the display shows the additional message “Warning! Exit Hygiene?” to prevent accidental exit from Hygiene mode. Press the [Y/+] key to acknowledge.
5. If there is any change to the existing setting, the display will show “Save?” Press the [Y/+] key to accept or the [N/-] key to discard and move to the next sub-menu.

Note: If a new Op Mode is saved, the display shows “Op Mode changed!!” when exiting the programming mode.

4.7.2 Change Site ID

The user can enter an 8-digit alphanumeric site ID in the programming mode. This site ID will be included in the datalog report.

1. “Change Site ID?” is the second sub-menu item in the Monitor Setup menu (Table 4.7).
2. Press the **[Y/+]** key and the display shows the current site ID: “Site ID = xxxxxxxx” with the left most digit flashing.
3. Press the **[Y/+]** or **[N/-]** key to cycle through all 26 letters and 10 numerals. Press **[MODE]** momentarily to advance to the next digit. The flashing digit will move to the next digit to the right. Repeat this process until all 8 digits of the new site ID are entered.
4. Press and hold the **[MODE]** key for 1 second to exit the data entry mode.
5. If there is any change to the existing site ID, the display shows “Save?” Press the **[Y/+]** key to accept the new site ID. Press the **[N/-]** key to discard the change and move to the next sub-menu.

4.7.3 Change User ID

The user can enter an 8-digit alphanumeric user ID in the programming mode. This user ID will be included in the datalog report.

1. "Change User ID?" is the third sub-menu item the Monitor Setup menu.
2. Press the **[Y/+]** key and the display shows the current user ID: "User ID = xxxxxxxx" with the left most digit flashing.
3. Press the **[Y/+]** or **[N/-]** key to cycle through all 26 letters and 10 numerals. Press **[MODE]** momentarily to advance to the next digit. The flashing digit will move to the next digit to the right. Repeat this process until all 8 digits of the new user ID are entered.
4. Press and hold the **[MODE]** key for 1 second to exit the data entry mode.
5. If there is any change to the existing user ID, the display shows "Save?" Press the **[Y/+]** key to accept the new user ID. Or press the **[N/-]** key to discard the changes and move to the next sub-menu.

4.7.4 Change Alarm Mode?

There are two different alarm modes: **Latched** and **Automatic Reset** (Auto Reset) in the MiniRAE 2000 that can be selected from the programming menu.

1. "Change Alarm Mode?" is the fourth sub-menu item in the Monitor Setup menu.
2. Press the [Y/+] key; the display shows the current alarm mode.
3. Press the [Y/+] key to accept the currently displayed alarm mode. Press [N/-] key to toggle to the other alarm mode. Press [MODE] to exit this sub-menu and move to the next monitor setup sub-menu.
4. If there is any change to the existing setting, the display will show "Save?" Press [Y/+] to save the change. Press [N/-] or [MODE] to discard the change and move to the next sub-menu.

4.7.5 Change User Mode

There are two different user modes: **Display** and **Program** that can be selected from the programming menu.

1. “Change User Mode?” is the fifth sub-menu item in the Monitor Setup menu (Table 4.7).
2. Press the [Y/+] key; the display shows the current user mode selected.
3. Press the [Y/+] key to accept the currently displayed user mode. Press [N/-] key to toggle to the alternate user modes. Press [MODE] to exit this sub-menu and move to the next monitor setup sub-menu.
4. If there is any change to the existing selection, the display shows messages “Program change” and “Are you sure?” Press [Y/+] to confirm the change or press [N/-] or [MODE] to discard the changes and move to the next sub-menu.

CAUTION: If the user mode is changed to **Display** mode, the user can no longer enter the programming mode. Therefore, the user can not change the user mode back to **Program** mode in normal mode.

To restore the user mode back to **Program** mode, turn the unit off and back on in Diagnostic Mode. Next enter Program mode by holding the [MODE] and [N/-] keys for three seconds. Enter the password at the prompt (the default is 0000). Once program mode is entered, go to the “Change Monitor Setup” / “Change User Mode” and change the mode back to **Program**.

An alternative way to change Display mode back to Program mode is through the PC and the ProRAE-Suite software.

4.7.6 Change Date

The MiniRAE 2000 monitor is equipped with a real time clock (RTC). The user can enter the correct date and time (see 4.7.7) for the real time clock.

1. “Change Date?” is the sixth sub-menu item in the Monitor Setup menu.
2. Press **[Y/+]** and the display shows the current date “mm / dd / yy” with the left most digit of the date flashing.
5. To modify this value, use the **[Y/+]** or **[N/-]** key to change the digit value and press the **[MODE]** key momentarily to advance to the next digit. The flashing digit will move on to next digit to its right. Repeat this process until the new date and time values are entered. Press and hold the **[MODE]** key for 1 second to exit data entry mode.
4. If there is any change to the existing value, the display shows “Save?” Press **[Y/+]** to confirm the new value or press **[N/-]** or **[MODE]** to discard the changes and move to the next sub-menu.

4.7.7 Change Time

To change the time in the RTC of the MiniRAE 2000:

1. “Change Time?” is the seventh sub-menu item in the Monitor Setup menu.
2. Press [Y/+] and the display shows the current time in the 24-hour format “hh : mm” with the left most digit of the time flashing.
3. To modify this value, use the [Y/+] or [N/-] key to change the digit value and press the [MODE] key momentarily to advance to the next digit. The flashing digit will move on to next digit to its right. Repeat this process until the new date and time values are entered. Press and hold the [MODE] key for 1 second to exit data entry mode.
4. If there is any change to the existing value, the display shows “Save?” Press [Y/+] to confirm the new value or press [N/-] or [MODE] to discard the changes and move to the next sub-menu.

4.7.8 Change Lamp

There are three UV lamps with different photon energies available for the PID sensor: **9.8 eV**, **10.6 eV** and **11.7 eV**. The user can select any one of the lamps from the programming mode.

1. “Change Lamp Type?” is the eighth sub-menu item in the Monitor Setup menu (Table 4.7).
2. Press the **[Y/+]** key; the display shows the current PID lamp selection.
3. Press the **[Y/+]** key to accept the currently displayed lamp. Press **[N/-]** key to scroll through the sub-menu for other lamp selections. Press **[MODE]** to exit this sub-menu and return to the next sub-menu in Table 4.7.
4. If there is any change to the existing selection, the display will show “Save?” Press **[Y/+]** to save the new selection or press **[N/-]** or **[MODE]** to discard the change and return to the next sub-menu in Table 4.7.

4.7.9 Change Unit

User can change the display and datalog unit from parts per million (ppm) to milli-gram per cubic meter (mg/m^3).

1. “Change Unit?” is the ninth sub-menu item in the Monitor Setup sub-menu.
2. Press the [Y/+] key, the display should show the current unit “Display Unit = ppm?” or “Display Unit = mg/m^3 ?”
3. Press [Y/+] key to accept the currently displayed unit. Press [N/-] key to toggle to the other unit. Press [MODE] key to exit this sub-menu.
4. If there is any change to the existing selection, press [Y/+] to confirm the new selection or press [N/-] or [MODE] to discard the changes and move to the next sub-menu.

Caution:

1. **The correction factor in the gas library is calculated based on “ppm” unit. If “mg” unit is selected, the built-in correction factor library is not valid.**
2. **No automatic conversion between “ppm” and “ mg/m^3 ” reading is performed by the monitor.**
3. **When the unit name is changed from “ppm” to “mg”, the unit must be recalibrated with the span gas concentration entered in mg/m^3 . The converse rule applies when the unit is changed from “mg” to “ppm”.**

4.7.10 Change Dilution Ratio

If a dilution system is used upstream of the MiniRAE 2000 inlet port, the user can enter the dilution ratio (from 1 to 10) to compensate the readings. The unit will then display the actual concentration of the gas before dilution. The dilution ratio should be 1 in normal operation where no dilution gas is applied to the sample gas. Dilution improves accuracy and linearity when the concentrations are above a few thousand ppm.

1. "Change Dilution Ratio?" is the tenth sub-menu item in the Monitor Setup menu.
2. Press the **[Y/+]** key; the display shows the current dilution ratio: "Dilution Ratio = xx" with the left most digit flashing.
3. Press the **[Y/+]** or **[N/-]** key to increase or decrease the value of the digit. Press **[MODE]** momentarily to advance to the next digit. The flashing digit will move to the next digit to the right. Repeat this process until both digits of the new dilution ratio are entered.
4. Press and hold the **[MODE]** key for 1 second to exit the data entry mode and move to the next sub-menu.
5. If there is any change to the existing dilution ratio, the display shows "Save?" Press **[Y/+]** to confirm the new value or press **[N/-]** or **[MODE]** to discard the changes and move to the next sub-menu.

4.7.11 Change Output?

There are two different external output options: DAC (Analog output) and Alarm in the MiniRAE 2000 that can be selected from the programming menu. The alarm output can be used to connect to the optional vibration alarm (vibrator) only. The analog output, which is proportional to the gas concentration, can be connected a chart recorder or can be queried by a computer to download data in real time (see Technical Note 141).

1. "Change External Output?" is the eleventh sub-menu item in the Monitor Setup menu.
2. Press the [Y/+] key and the display shows the current output option selection: "Output = DAC?"
3. Press the [Y/+] key to accept the currently displayed output option. Press [N/-] to change to the other external option: "Output = Alarm?" Press [MODE] to exit this sub-menu and move to the next monitor setup sub-menu.
4. If there is any change to the existing selection the display will show "Save?" Then, press [Y/+] to save the change, press [N/-] to go back to Step 2, or press [MODE] to exit this sub-menu and move to the next monitor setup sub-menu.

4.7.12 Change DAC Range?

There are four different DAC (Digital-to-Analog Conversion) range values available in the **MiniRAE 2000: 20, 200, 2000 and 10K ppm**. The maximum 2.5V DC analog signal output from the unit will represent the range value chosen. (See for analog signal output connection.)

1. “Change DAC Range?” is the twelfth sub-menu item in the Monitor Setup menu.
2. Press the [Y/+] key, the display shows the current DAC Range value: “DAC Range = 2000 ppm?”
3. Press the [Y/+] key to accept the currently displayed value. Press [N/-] to scroll through the sub-menu for other range values. Press [MODE] to exit this sub-menu and return to the first sub-menu in Table 4.7.
4. If there is any change to the existing selection, press the [Y/+] key and the display will show “Save?” Press the [Y/+] key to save the change or press the [N/-] key to discard and return to the first sub-menu in Table 4.7.

4.7.13 Set Temperature Unit?

The temperature display can be switched between Fahrenheit and Celsius units.

1. "Set Temperature Unit?" is the thirteenth sub-menu item in the Monitor Setup menu.
2. Press the [Y/+] key, and the display shows the current setting: "Temperature Unit = Fahrenheit?"
3. Press the [Y/+] key to accept the currently displayed value. Press [N/-] to select the sub-menu "Temperature Unit = Celsius?" Press [MODE] to exit this sub-menu and return to the first sub-menu in Table 4.7.
4. If there is any change to the existing selection, press the [Y/+] key and the display will show "Save?" Press the [Y/+] key to save the change and return to the first sub-menu in Table 4.7 or press the [N/-] key to discard and return to Step 3..

4.8 Exit Programming Mode

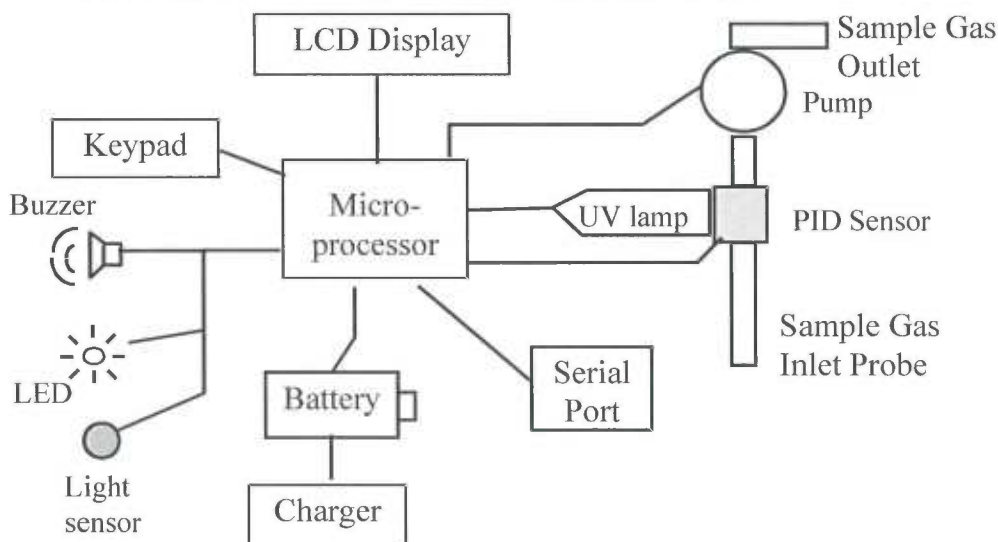
1. To exit programming mode from the first tier menu level, press the **[MODE]** key once.
2. To exit programming mode from 2nd tier sub-menu, press the **[MODE]** key twice.
3. To return to programming mode, press and hold down both the **[MODE]** and **[N/-]** keys for 3 seconds.

5. THEORY OF OPERATION

The MiniRAE 2000 monitor uses a newly developed electrodeless discharge UV lamp as the high-energy photon source for the PID. As organic vapors pass by the lamp, they are photo-ionized and the ejected electrons are detected as a current. The PID sensor with a standard 10.6 eV lamp detects a broad range of organic vapors. A lamp with high photon energy (e.g. 11.7 eV) will measure the more kinds of compounds, whereas low photon energies (e.g. 9.8 eV) are selective for easily ionizable compounds such as aromatics. In principle, any compound with an ionization energy lower than that of the lamp photons can be measured.

The PID sensor for the MiniRAE 2000 monitor is constructed as a small cavity in front of the UV lamp. A diaphragm pump draws the gas sample into the sensor and then pumps it out through the side of the instrument.

Figure 5-1 MiniRAE 2000 Block Diagram



THEORY OF OPERATION

A single chip microcomputer is used to control the operation of the alarm buzzer, LED, pump and light sensor. It measures the sensor readings and calculates the gas concentrations based on calibration to known standard gases. The data are stored in non-volatile memory so that they can be sent to a PC for record keeping. RS-232 transceivers provide a serial interface between the monitor and the serial port of a PC. An LCD display consisting of a single row of eight alpha/numeric characters is used to display the readings. The user interacts with the monitor through three keys on the front panel keypad.

A rechargeable NiMH, NiCd battery, or an alkaline battery pack powers the monitor.

6. MAINTENANCE

The major maintenance items of the MiniRAE 2000 are:

- Battery pack
- Sensor module
- PID lamp
- Sampling pump
- Inlet connectors and filters

Note: Maintenance should be performed by qualified personnel only.

NOTE: The printed circuit board of the monitor is connected to the battery pack even if the power is turned off. Therefore, it is very important to disconnect the battery pack before servicing or replacing any components inside the monitor. Severe damage to the printed circuit board or battery may occur if the battery pack is not disconnected before servicing the unit.

6.1 Battery Charging and Replacement

When the display shows a flashing message “Bat”, the battery requires recharging (see Section 3.1 for Battery charging). It is recommended to recharge the MiniRAE 2000 monitor upon returning from fieldwork. A fully charged battery runs a MiniRAE 2000 monitor for 10 hours continuously. The charging time is less than 10 hours for a fully discharged battery. The built-in charging circuit is controlled by the micro-controller to prevent over-charging. The battery may be replaced in the field (in area known to be non-hazardous) if required.

WARNING

To reduce the risk of ignition of hazardous atmospheres, recharge battery only in area known to be non-hazardous. Remove and replace battery only in area known to be non-hazardous.

Replacing Battery Pack

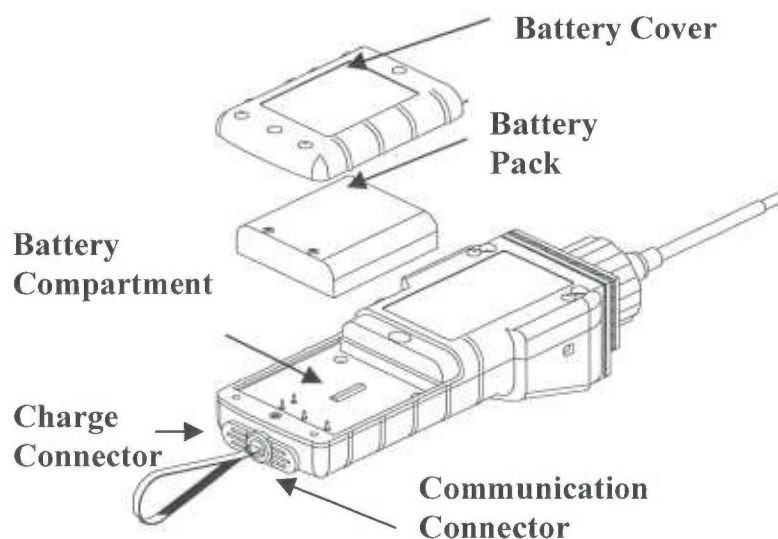


Figure 6-1 Battery Replacement

1.

MAINTENANCE

Turn off the power of the MiniRAE 2000.

2. Unscrew the two battery compartment screws, located on the bottom of the monitor, and remove the cover.
3. Remove the battery pack from the battery compartment.
4. Replace a fully charged spare battery pack inside the battery compartment. Make sure the battery pack is oriented properly inside the compartment
5. Close the battery cover and tighten the two screws.

Replacing Alkaline Battery Adapter

1. Insert four fresh AA size alkaline batteries into the alkaline battery holder. Make sure that the polarity of the batteries is correct.
2. Follow the same procedure as described above to replace the battery holder.

Note: The internal charging circuit is designed to prevent charging to alkaline batteries.

6.2 PID Sensor & Lamp Cleaning/Replacement

The sensor module is made of several components and is attached to the lamp-housing unit as shown in Figure 7-2.

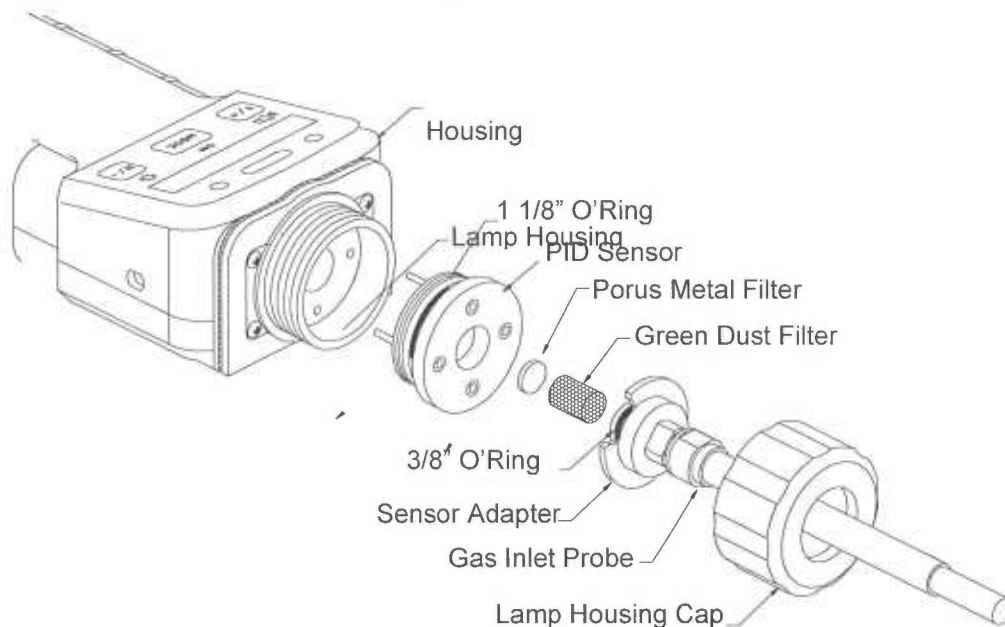


Figure 7-2 Sensor Components

Note: Normally the cleaning procedure is not needed. Clean the PID sensor module, the lamp and the lamp housing only when one of the following happened:

1. The reading is inaccurate even after calibration.
2. The reading is very sensitive to air moisture.
3. A chemical liquid has been sucked into the unit and damaged the unit.

Use of the water trap filter will help prevent contamination and accidentally drawing liquid into the sensor.

To access the sensor components and lamp, gently unscrew the lamp-housing cap, remove the sensor adapter with the gas inlet probe and the metal filter all together. Then hold the PID sensor and pull straight out to avoid bending the electrical pins on the sensor (see Figure 7-2). A slight, gentle rocking motion helps release the sensor.

To clean the PID sensor:

Place the entire PID sensor module into GC grade methanol. It is highly recommended that an ultrasound bath to be used to clean the sensor for at least 15 minutes. Then dry the sensor thoroughly. Never touch the electrodes of the sensor by hand.

Also use a methanol-soaked cotton swab to wipe off the lamp housing where it contacts the sensor when the sensor is installed.

Turn over the sensor so that the pins point up and the sensor cavity is visible. Examine the sensor electrodes for any corrosion, damage, or bending out of alignment. The metal sensor electrode “fingers” should be flat and straight. If necessary, carefully bend the sensor fingers to ensure that they do not touch the Teflon portions and that they are parallel to each other. Make sure that the nuts on the sensor pins are snug but not overtight. If the sensor is corroded or otherwise damaged, it should be replaced.

To clean lamp housing or change the lamp:

To clean lamp housing or change the lamp:

If the lamp does not turn on, the monitor will display an error message to indicate replacement of the lamp may be required.

1. If the lamp is operational, clean the lamp window surface and the lamp housing by wiping it with GC grade methanol using a cotton swab using moderate pressure. After cleaning, hold the lamp up to the light at an angle to detect any remaining film. Repeat the process until the lamp window is clean. Never use water solutions to clean the lamp. Dry the lamp and the lamp housing thoroughly after cleaning.

CAUTION: Never touch the window surface with the fingers or anything else that may leave a film. Never use acetone or aqueous solutions.

2. If the lamp does not turn on, remove the lamp from the lamp housing. Place the lamp O-ring onto the new lamp. Insert the new lamp, avoiding contact with the flat window surface.
3. Reinstall the PID sensor module.
4. Tighten the Lamp Housing Cap.
5. If the lamp type has been changed, adjust the lamp type setting in the programming mode (Section 4.7.8).

6.3 Sampling Pump

When approaching the end of the specified lifetime of the pump, it will consume higher amount of energy and reduce its sample draw capability significantly. When this occurs, it is necessary to replace or rebuild the pump. When checking the pump flow, make sure that the inlet connector is tight and the inlet tubing is in good condition. Connect a flow meter to the gas inlet probe. The flow rate should be above 450 cc/min when there is no air leakage.

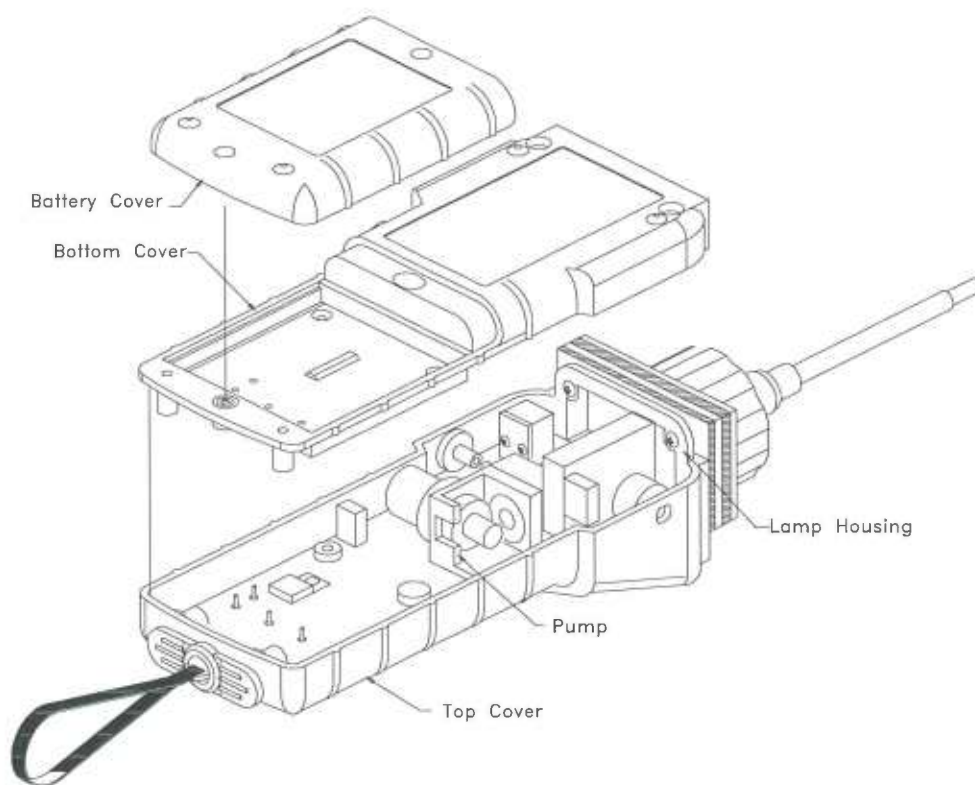


Figure 7-3 Sampling Pump

Pump Replacement

1. Turn off the MiniRAE 2000 power.
2. Open the battery cover, remove the battery pack, and carefully unscrew the six screws to open the bottom cover.
3. Unplug the pump from the PCB. Unscrew the two screws that hold the pump assembly to the PCB. Disconnect the Tygon tubing that connects the pump to the gas inlet port and gas outlet port.
4. Insert a new pump assembly. Connect the Tygon tubing to the gas inlet port. Plug the pump connector back into the PCB and screw down the pump assembly to the board.
5. Replace the bottom cover and tighten the six screws. Reconnect the battery pack. Replace the battery pack and its cover.

6.4 Turning on the UV Lamp

The UV lamp is made of a glass envelope and a UV window (salt crystal) on one end of the envelope. The inside of the lamp is filled with low pressure gases. To turn on the lamp, a high voltage electric field is applied from the outside of the glass envelope. The molecules inside the lamp are ionized and produce a glow discharge that generates the UV light. The MiniRAE 2000 has a built-in sensing mechanism to monitor the status of the UV lamp and display a “Lamp” error message if it is not on.

If the UV lamp has not been used for a long period of time (> 1 month) or is cold, it may become slightly harder to turn on. If such a condition occurs, the “Lamp” message will appear in the monitor display during the power on sequence. This phenomenon is more significant in 0.25” UV lamps used in ToxiRAE and MultiRAE Plus products, because of the relatively small lamp size. To solve this problem, simply turn on and off the monitor a few times and the lamp should turn on. After the UV lamp is turned on for the first time, it should be easier to turn on the UV lamp next time.

It is possible that the UV lamp is actually on when the lamp error message appears. This is because when the lamp becomes old, the internal threshold level to detect lamp failure may have shifted and cause a false alarm. To eliminate such possibility, simply check to see the UV lamp is actually on. This can be done easily by removing the sensor cap and observing the glow light of the UV lamp in a dark place. The user can also feed the monitor with calibration gas and observe if the sensor reading changes. If the reading changes significantly with the gas, the UV lamp is actually on.

A possible failure mechanism for the UV lamp is a leak developed along the seal of the glass envelope. When such condition occurs, the lamp will become very hard or impossible to turn on and will need to be replaced.

7. TROUBLESHOOTING

To aid the user in diagnosing the monitor, a special diagnostic mode can be used displays critical, low level parameters. Section 7.1 describes the operation of the diagnostic mode. Section 7.2 summarizes the frequently encountered problems and suggested solutions. By turning on the MiniRAE 2000 monitor in diagnostic mode and by using the troubleshooting table in Section 7.2, the user can usually correct the problem without having to return the monitor for repair.

WARNING

This function should be used by qualified personnel only! The diagnostic mode allows the user to set several low-level parameters that are very critical to the operation of the monitor. Extra care should be taken when setting these parameters. If the user is not familiar with the function of these parameters and sets them incorrectly, it may cause the monitor to shut down or malfunction.

TROUBLESHOOTING

7.1 Troubleshooting Table

Problem	Possible Reasons & Solutions
Cannot turn on power after charging the battery	Reasons: Discharged battery. Defective battery. Microcomputer hang-up. Solutions: Charge or replace battery. Disconnect, then connect battery to reset computer.
No LCD back light	Reasons: Trigger level too low, the current mode is not user mode, and the mode does not support automatic turn on back light. Solutions: Adjust trigger level. Verify the back light can be turned on in user mode. Call authorized service center.
Lost password	Solutions: Call Technical Support at +1.408 .752 .0723 or +1. 888 .723 .4800
Reading abnormally High	Reasons: Dirty sensor module. Dirty water trap filter. Excessive moisture and water condensation. Solutions: Clean sensor module and lamp housing. Replace water trap filter. Blow dry the sensor module.
Buzzer Inoperative	Reasons: Bad buzzer. Solutions: Call authorized service center.

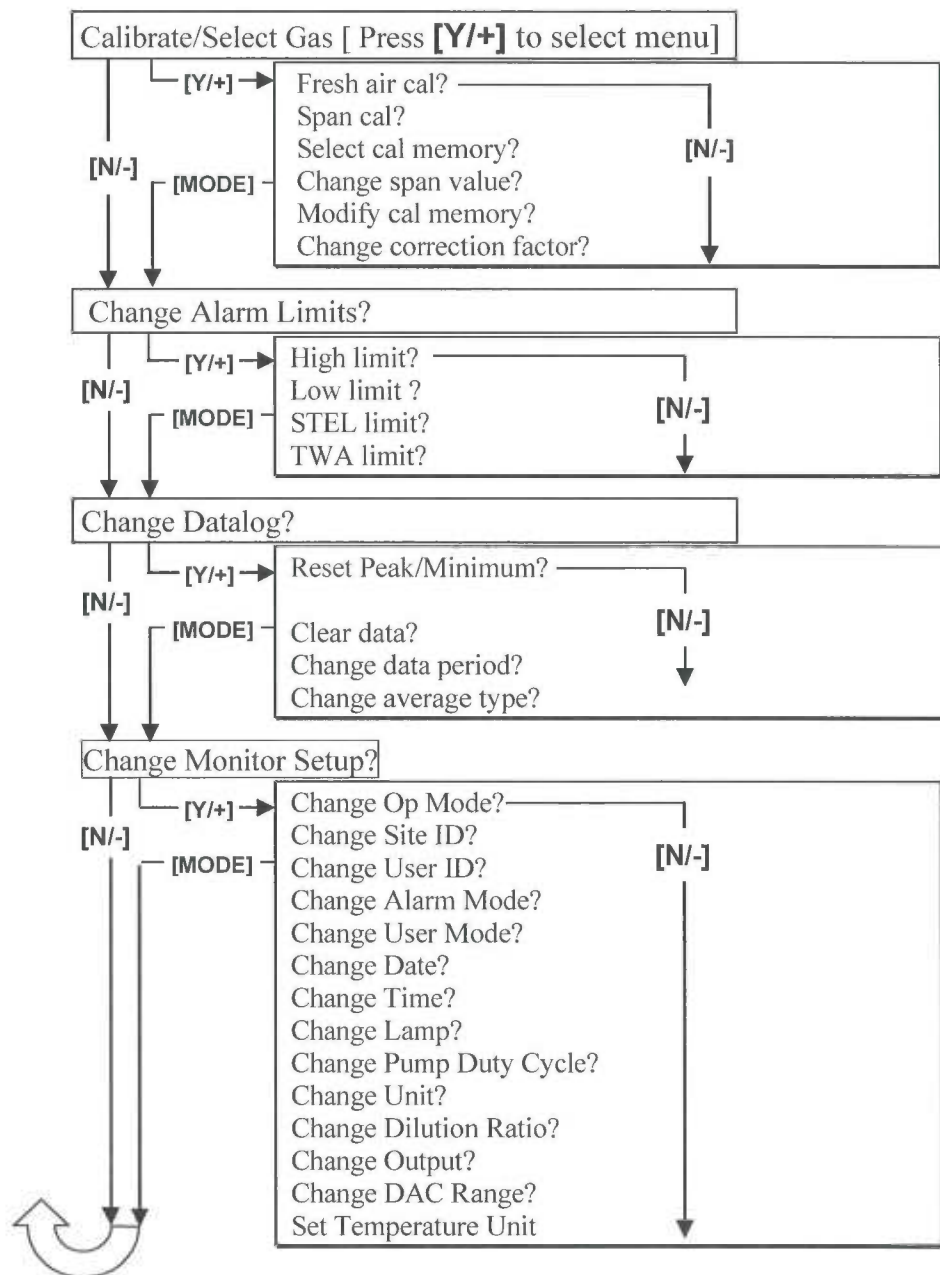
TROUBLESHOOTING

Inlet flow too low	<p>Reasons: Pump diaphragm damaged or has debris. Flow path leaks.</p> <p>Solutions: Check flow path for leaks; sensor module O-ring, tube connectors, Teflon tube compression fitting. Replace pump or diaphragm.</p>
"Lamp" message during operation	<p>Reasons: Lamp drive circuit. Weak or defective PID lamp, defective.</p> <p>Solutions: Turn the unit off and back on Replace UV lamp</p>
Full scale measurement in humid environment	<p>Reasons: Dirty or wet sensor.</p> <p>Solutions: Clean and dry sensor and lamp housing. Adjust sensor fingers to ensure not touching Teflon. Use water trap filter.</p>
Reading abnormally low	<p>Reasons: Incorrect calibration. Low sensitivity to the specific gas. Weak or dirty lamp. Air leakage.</p> <p>Solutions: Calibrate the monitor. Replace sensor. Clean or replace lamp. Check air leakage.</p>

APPENDIX A. QUICK REFERENCE GUIDE

Press [N/-] and [MODE], simultaneously, for 3 seconds, to enter Programming Mode. Press [MODE] to return to Survey Mode.

PROGRAMMING MODE



RAE Systems, Inc. Contact Information

Main Office: 3775 N. First St.
San Jose, CA 95134-1708
USA

Telephone: 408-952-8200

Fax: 408-952-8480

Instrument Sales: 877-723-2878

Email: RaeSales@raesystems.com

Website: www.raesystems.com

Technical Service: 888-723-4800

Tech@raesystems.com

Special Note

If the monitor needs to be serviced, contact either:

1. The RAE Systems distributor from whom the monitor was purchased; they will return the monitor on your behalf.
2. The RAE Systems Technical Service Department. Before returning the monitor for service or repair, obtain a Returned Material Authorization (RMA) number for proper tracking of your equipment. This number needs to be on all documentation and posted on the outside of the box in which the monitor is returned for service or upgrade. Packages without RMA Numbers will be refused at the factory.

APPENDIX C



Maintenance Guide

For the H.01L and Sm.Oil Oil / Water Interface Meters

This interface is designed to measure the thickness of floating product (L.N.A.P.L.). It will also detect and measure sinking layers of L.N.A.P.L.s.

This instrument has been designed and built to give years of reliable and accurate use.

Please follow the simple guidelines given in this booklet for the best performance from your unit.

Signals indicate the following:

The continuous tone and light indicates product (hydrocarbon). Intermittent tone and light indicates water.

General Hints

Cold Weather

In cold weather condensation will form on the lens as it enters the well and contacts the warmer moist air in the well. This causes the unit to sound as product. To overcome this allow the probe to acclimatize in the well or lower the probe into the water, then take readings.

A dirty or scratched probe lens aggravates this problem.

Removing The Probe

This requires two wrenches - a 1/2"AF and 9/16"AF. When the knurled nut has been loosened the link may be still tight in the probe. Gently separate the link from the probe by hand. Care must be taken to avoid either breaking the wires while removing the probe or crimping the wire while replacing the probe.

Do...

- Avoid sharp edged casing
- Avoid entanglement with other equipment in boreholes and wells.
- Clean and dry probe after use
- Rewind tape onto reel after each use

Warranty is conditional upon adherence to these guide lines.

Do Not...

- Do not use to plumb borehole depths
- Do not use as guide to backfilling with sand etc. Instrument may get locked in sand.

Remember to...

- CLEAN THE UNIT AFTER USE
- AVOID SCRATCHING THE LENS
- HANG THE UNIT ON THE CASING WHERE POSSIBLE, AND RUN THE TAPE OVER THE FRAME LEG. THIS PROTECTS THE TAPE AGAINST CUTS AND NICKS
- THIS IS A TOOL TO HELP YOU TO DO YOUR JOB WELL. TREAT IT PROPERLY AND IT WILL NOT LET YOU DOWN

IF YOU HAVE ANY OTHER QUESTIONS OR COMMENTS
CALL 1-800-331-2032 OR YOUR SUPPLIER.

Tips For Using The Oil/Water Interface Meter

THE WAY IT WORKS

IN AIR the infrared emitter sends out an I/R beam inside a 45 degree prism.

The I/R beam reflects off the internal face of the prism to the opposite face, which then reflects the beam to the detector.

In this state the instrument is silent.

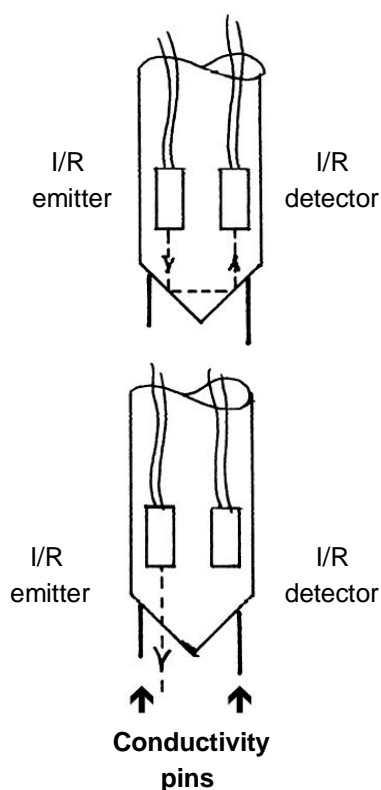
IN FLUIDS which are denser than air, the SNELL principle operates.

The I/R beam is not reflected internally, but exits the prism. The detector does not detect the I/R beam.

In this state the instrument emits a tone and the red light is on.

At the same time the two conductivity probes are testing for conductivity.

If the fluid does not conduct electricity, the sound tone and light are solid (product) If the fluid does conduct electricity, the tone is intermittent (water).



Care of Reel

Remove electronic front panel before wash down.

Reel may be cleaned with the following:

Aliphatics: Hexane, Heptane, White Kerosene, Mineral Spirits

Alcohols: Methyl, Isopropyl, Isobutyl
1 + 3 Denatured Alcohol

Halogenated Freons TF + TE

Hydrocarbons:

Others: Soap solution Naptha Alconox 10%, Fantastic[®], Windex[®], Joy[®], Top Job[®], Mr. Clean[®], Formula 409[®].

[®] Registered Trade Marks

Care of Tape and Probe

Tape and Probe may be cleaned and de-greased with the following:

Alcohols: Hexane, Heptane

Aliphatics: Hexane, Heptane, White Kerosene, Mineral Spirits

Halogenated Fully Halogenated Freon

Hydrocarbons:

Others: Soap Solution, Naptha Alconox 10%, Joy detergent[®] 10%, Lestoil[®]

Do Not clean with abrasives.

The Probe lens is made from an Amorphous Thermoplastic, highly resistant to many chemicals, however, contact with the following should be avoided or approached with caution:

Chloroform I.I.2. Cresol, Iodine, Oleum, Resorcinol

Partially Halogenated Hydrocarbons such as Methylene Chloride, Phenol (saturated solution) should be approached with care. Exposure to any of the above causes damage to the instrument

English

INSTRUCTIONS

PRESS BUTTON = METER ON FOR 4 MINUTES

GREEN LIGHT ON = METER ACTIVE - BATTERY GOOD

GREEN LIGHT OFF = METER OFF OR BATTERY NO GOOD

INTERFACE METER

GROUND METER WITH LEAD PROVIDED

OIL STEADY LIGHTS AND BUZZER TONE

TAKE MEASUREMENTS GOING THROUGH THE OIL INTO THE WATER, THEN BACK FROM THE WATER INTO THE OIL - REPEAT TO GET CONSTANT READING

AFTER USE

REMOVE EXCESS MOISTURE

CLEAN PROBE AND TAPE WITH SOAP AND WATER

- DO NOT USE ABRASIVES OR SOLVENTS •

PROTECT AND MAINTAIN POLISHED PROBE TIP FOR TOTAL WASHDOWN -
REMOVE ELECTRONIC PANEL FROM REEL. DO NOT WASH ELECTRONICS.
DRY REEL AND REPLACE ELECTRONIC PANEL.

Spanish

INSTRUCCIONES

OPRIMA EL BOTON = MEDIDOR EN MARCHA DURANTE 4 MINUTOS
LUZ VERDE ENCENDIDA = MEDIDOR EN MARCHA - BATERIA EN BUEN ESTADO
LUZ VERDE APAGADA = MEDIDOR DETENIDO - BATERIA AGOTADA

MEDIDOR DE INTERFAZ

PONGA EL MEDIDOR A TIERRA CON EL CONDUCTOR PROVISTO
PETROLEO = LUCES Y ALARMA SONORA PERMANENTES
AGUA = LUCES Y ALARMA SONORA INTERMITENTES
TOME LAS MEDIDAS PASANDO DEL PETROLEO AL AGUA, LUEGO DEL AGUA AL
PETROLEO - REPITA PARA OBTENER LECTURAS CONSTANTES.

DESPUES DEL USO

ELIMINAR EL EXCESO DE HUMEDAD
LIMPIAR LA Sonda Y CINTA CON AGUA JABONOSA
* **NO USAR ABRASIVOS NI SOLVENTES** *
PROTEGER Y MANTENER LIMPIA LA PUNTA DE LA Sonda

PARA LIMPIEZA TOTAL - SACAR EL PANEL ELECTRONICO DEL CARRETE. NO
LAVE LOS DISPOSITIVOS ELECTRONICOS. SECAR EL CARRETE Y VOLVER A
COLOCAR EL PANEL ELECTRONICO.

French

INSTRUCTIONS

APPUYER SUR LE BOUTON = APPAREIL DE MESURE EN MARCHÉ PENDANT 4
MINUTES.
TÉMOIN VERT ALLUMÉ = APPAREIL DE MESURE EN MARCHÉ - PILE EN BON
ÉTAT.
TÉMOIN VERT ÉTEINT = APPAREIL À L'ARRÊT OU PILE MAUVAISE.

APPAREIL DE MESURE-INTERFACE

METTRE L'APPAREIL À LA TERRE À L'AIDE DU CONDUCTEUR FOURNI.
PÉTROLE = TÉMOIN ET AVERTISSEUR CONTINUELLEMENT ALLUMÉS.
EAU = TÉMOIN ET AVERTISSEUR ALLUMÉS PAR INTERMITTENCE.
PRENDRE DES MESURES EN PASSANT DU PÉTROLE À L'EAU, PUIS DE L'EAU
AU PÉTROLE. RÉPÉTER POUR OBTENIR UNE LECTURE UNIFORME.

APRÈS USAGE

ENLEVER L'EXCÈS D'HUMIDITÉ.

NETTOYER LA SONDE ET LE RUBAN AVEC UNE SOLUTION D'EAU SAVONNEUSE.

*** NE PAS UTILISER DE SOLVANT NI DE PRODUIT ABRASIF. ***

PROTÉGER ET GARDER LA POINTE DE LA SONDE BIEN PROPRE.

POUR UN NETTOYAGE TOTAL - ENLEVER LE PANNEAU ÉLECTRONIQUE DU DÉVIDOIR. NE PAS NETTOYER LES ÉLÉMENTS ÉLECTRONIQUES. SÉCHER LE DÉVIDOIR ET REMETTRE LE PANNEAU ÉLECTRONIQUE.

German**BEDIENUNGSANLEITUNG**

KNOPF DRÜCKEN = MESSGERÄT IST 4 MINUTEN AN

GRÜNES LICHT AN = MESSGERÄT AKTIV - BATTERIE GUT

GRÜNES LICHT AUS = MESSGERÄT AUS ODER SCHLECHTE BATTERIE

SCHNITTSTELLEN-MESSER

ERDSCHLUSS-MESSGERÄT MIT MITGELIEFERTEM ANSCHLUSSDRAHT.

Ö L = ANHALTENDES AUFLEUCHTEN DER LAMPEN UND SUMMERTON

WASSER = INTERMITTIERENDES AUFLEUCHTEN DER LAMPEN UND SUMMERTON

NEHMEN SIE MESSUNGEN VOR, INDEM SIE DURCHS ÖL INS WASSER STOSSEN, DANN ZURÜCK VOM WASSER INS ÖL. UM KONSTANTE ABLESUNGEN ZU ERZIELEN, MÜSSEN SIE DIESES VERFAHREN WIEDERHOLEN.

NACH GEBRAUCH

ÜBERSCHÜSSIGE FEUCHTIGKEIT ENTFERNEN.

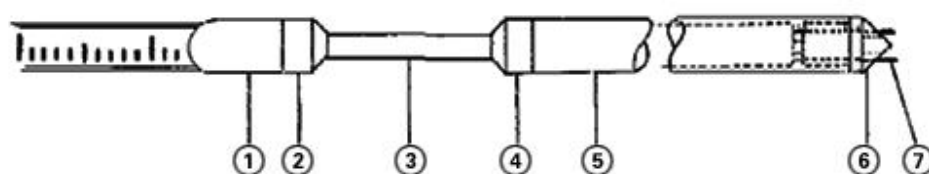
MESS-SONDE UND BAND MIT SEIFE UND WASSER SÄUBERN.

*** KEINE SCHEUER-ODER LÖSUNGSMITTEL ANWENDEN ***

DIE POLIERTE SONDENPRÜFSPITZE MUSS GESCHÜTZT UND GEGEWARTET WERDEN.

ZUR KOMPLETTEN WASCHUNG MUSS DIE ELEKTRONIKTAFEL VON DER SPULE ABMONTIERT WERDEN. NICHT DIE ELEKTRONIK WASCHEN! DIE SPULE TROCKNEN UND DIE ELEKTRONIKTAFEL WIEDER ANMONTIEREN.

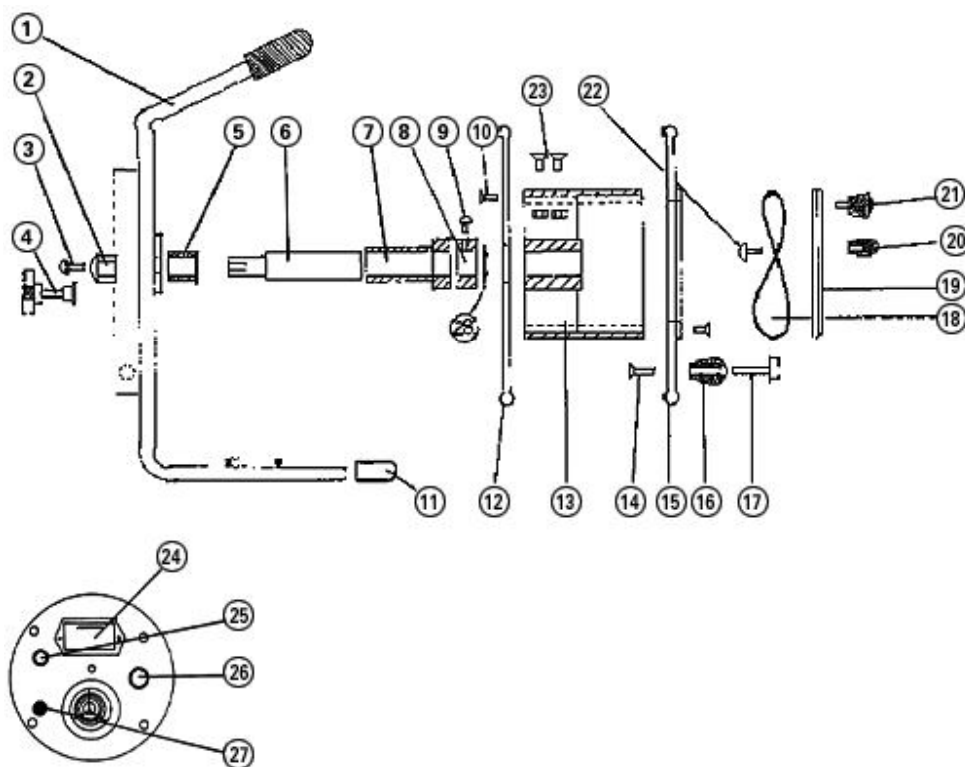
Probe Electronics



- | | | | |
|-----------|----------------------|---------------|-------------------|
| 1 0100-41 | Tape Connector | 5 0100-35/43 | Probe Body |
| 2 0100-34 | Link/Tape Connector | 6 0100-38 | 1/F Lens.WLM Tip. |
| | | (WLM)-36(1/F) | |
| 3 0100-42 | Link | 7 0100-39 | Conductivity Pins |
| 4 0100-40 | Link/Probe Connector | 8 0100-45/44 | Reel Electronics |

Note: Items 1 to 8 are servicable only by supplier.

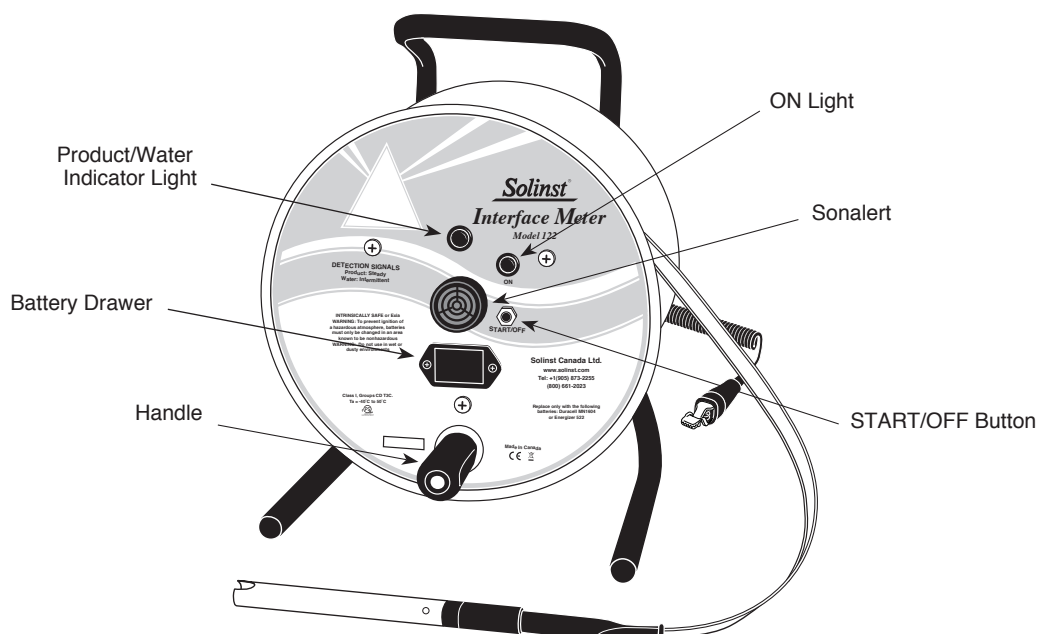
Reel Electronics



- | | | | |
|-------------|-------------|---------------|---------------------|
| 1 01001A1B | Frame | 15 0100-3 | Front Plate |
| 2 0100-9 | Nut | 16 0100-5 | Cranking Handle |
| 3 0100-23 | Screw | 17 0100-11 | Spindle |
| 4 0100-6/24 | Brake | 18 0100-18 | O Ring |
| 5 0100-18 | Spacer | 19 0100-56 | Electric Disk |
| 6 0100-8 | Shaft | 20 0100-54 | Disk Handle |
| 7 0100-13 | Bearing | 21 0100-55/68 | Disk Retaining Knob |
| 8 0100-15 | Ground Ring | 22 0100-71 | Screw |

9	0100-62	Screw	23	0100-59/60	Tape Screws
10	0100-20	Screw	24	0100-53	Battery Holder
11	0100-7	Frame Boot	25	0100-48/49	Battery L.E.D.
12	0100-2	Rear Plate	26	0100-46/47	Oil/Water L.E.D.
13	0100-4	Hub	27	0100-50/51	On/Off Button
14	0100-12	Screw	28	0100-14	Bearing Retainer

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Operating Principle

The Solinst Model 122 Interface Meter has a narrow 5/8" (16 mm) diameter probe and uses laser-marked PVDF flat tape. It is certified to CSA Standards, for use in hazardous locations Class 1, Groups C & D. It has an infra-red circuit which detects the presence of a liquid. A conductivity circuit differentiates between conductive liquid (water) and non-conductive liquid (LNAPL or DNAPL product).

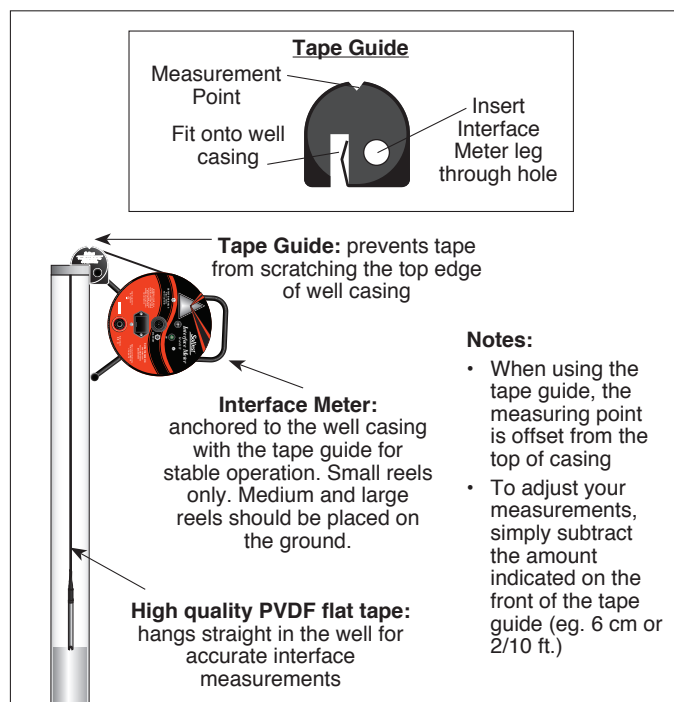
Equipment Check

Before beginning any measurements, check the electronics and battery condition by pushing the 'START/OFF' button. A brief tone and red light indicate that the meter is functional.

A flashing green light indicates the meter is on. It will automatically turn off after 10 minutes to preserve battery life.

Using the Tape Guide

1. The tape guide has been designed to: improve accuracy when reading interface measurements; to prevent the laser-marked PVDF flat tape being cut by well casing; and to allow the tape and probe to hang straight from the side of the well.
2. If interface measurements are being taken in a 2" dia well then simply fit the small end of the tape guide onto the edge of the well casing.
3. The small end must be inserted if the Interface Meter is to be suspended from the tape guide.
4. Insert the leg of the Interface Meter into the hole on the Tape Guide (small reels only).
5. Once inserted, rest the Interface Meter on the side of the well casing.



Field Measurements

IMPORTANT

1. To meet safety requirements and to protect the electronics from damage, always ground the meter by attaching the grounding clip to the metal well casing or to a suitable ground rod.

Continued overleaf...

2. Push the 'START/OFF' button. A brief tone and light indicate that the meter is functional and the flashing green light indicates that the meter is on. The meter automatically turns off after 10 minutes. Press the 'START/OFF' button as necessary during operation to turn the meter back on.
3. Place the slotted part of the tape guide onto the edge of the well casing. Lay the Interface Meter laser-marked PVDF flat tape into the groove on the top of the tape guide. Measurements will be read at the apex of the V-notch on the tape guide.

Note: When using the tape guide, remember to subtract the compensation factor stamped onto the side of the guide from each measurement.

4. A steady tone and light indicates a non-conductive liquid (e.g. product). An intermittent tone and light indicates a conductive liquid (e.g. water).
5. For floating product (LNAPL), take the air/product interface measurement on the way into the liquid, and the water/product interface on the way up. When passing through product into water, some product may adhere to the probe sensors due to surface tension. Therefore, when water is detected below product, the probe should be raised and lowered rapidly in a short vertical motion to remove any product that may have been carried down with the probe.
6. The water/product interface should then be measured as the probe is raised very slowly back up. Once the interface is detected the probe can be raised and lowered in small increments to precisely determine the interface.
7. Repeat measurements to confirm water/product interface.
8. To determine the thickness of product, subtract the water/product interface from the product/air interface.
9. To determine if there is any sinking product (DNAPL) in the well, continue lowering the probe slowly. If steady signals activate, determine the top of the sinking layer by reading directly from the PVDF flat tape. Continue lowering the probe slowly until the tape slackens when the well bottom is reached. Read the level directly from the PVDF flat tape and subtract one from the other to determine thickness.
10. Upon completion of readings clean the tape and probe; as described in the Cleaning and Maintenance section.

Cleaning and Maintenance

After each use, the laser-marked PVDF tape should be wiped clean and carefully rewound onto the reel.

The probe should be cleaned as follows:

- Wash probe thoroughly with a non-abrasive mild detergent. **DO NOT USE ANY SOLVENTS.** Use a soft cloth around the pins on the end of the probe to remove all product. Use the brush provided to remove all product from inner part of the probe.

USE LUKE-WARM, NOT HOT WATER. DAMAGE TO THE PROBE MAY RESULT.

- Rinse probe thoroughly with distilled water, wipe dry.
- Return the probe to the holder.

Other suitable cleaning method:

- Steam clean the PVDF flat tape only.

Battery Replacement

Push the battery drawer in and up and then release. The battery drawer should eject slightly, allowing it to be pulled out. Replace the 9V alkaline battery.

Other General Tips:

1. The probe should be cleaned after each use.
2. Always use the grounding cable.
3. Do not drop probe: damage to probe tip may result.
4. If battery is weak, the start tone will not sound, and flashing "green" light will be off. Replace the 9V alkaline battery.
5. Before storage, make sure the meter is turned off. If the Interface Meter is going to be stored for longer than two months, the 9V alkaline battery should be removed to avoid potential leakage.
6. The meter can be checked by placing the probe in distilled (non-conductive) water or pure phase product, for example lamp oil (**avoid bright sunlight during testing and resting the probe on the bottom of the container**). A steady tone and light should be observed.

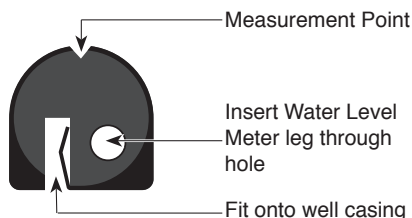
Equipment Check

1. Turn sensitivity dial **fully clockwise**.

Notes: 1. Clockwise rotation of sensitivity dial turns meter on and increases sensitivity.
2. Always set switch to highest sensitivity position, then decrease if necessary.

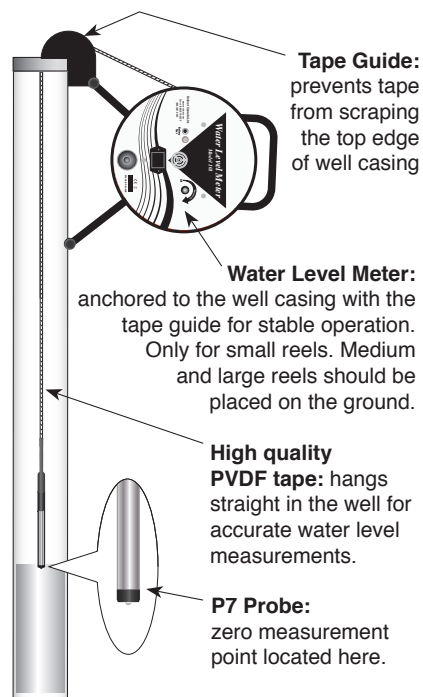
2. Depress the Battery Test button to test the battery and circuitry (excluding the probe when not in use).
3. Submerge the probe in tap water. This completes the circuit and activates the buzzer and light.

The Tape Guide



The Tape Guide has been designed to:

- Improve accuracy when reading water levels,
 - Easily obtain repeatable measurements,
 - Prevent tape being cut by well casing,
 - Allow the tape and probe to hang straight from the side of the well.
1. Fit the small end of the Tape Guide onto the edge of well casing 2" (50 mm) diameter or larger.
 2. Insert the leg of the Water Level Meter into the hole on the Tape Guide and rest the Water Level Meter on the side of the well casing. (See diagram above).
 3. To store the Tape Guide, simply clip it onto the support bracket located on the back of the Water Level Meter.



Water Level Measurements

1. The P7 Probe zero measurement point is located near the tip of the probe.
2. For ease of operation the Tape Guide can be used to support the Water Level Meter. (See diagram above).
3. Feed the tape into and out of the well using the groove in the top of the Tape Guide. The light and buzzer activate when the black Delrin tip is submerged and the zero point is reached. To ensure accuracy, lower and raise the probe a few times and then record the depth measurement from the tape at the top of the well.
4. When using the Tape Guide, the measuring point is offset from the top of casing. To adjust your measurements to the top of the casing, simply subtract the amount indicated on the front of the Tape Guide (i.e. 6 cm or 2/10 ft).

Routine Care

1. After the depth to water has been recorded, the tape should be carefully rewound onto the reel, the probe wiped dry and placed into the probe holder.
2. The probe, tape and reel can be cleaned with phosphate free (non-abrasive) detergent and warm water.
3. Use of a Water Level Meter Carrying Bag adds to the service life of the meter.
4. Use of the Tape Guide adds to the life of the tape.

Probe Care and Cleaning

1. The P7 Probe should be wiped clean after each use.
2. Remove any dirt or water from around the central sensor pin.
3. If the central sensor pin is corroded or coated, use emery cloth to polish it.
4. After cleaning, place probe back in its holder.

Battery Replacement

- Battery type - alkaline, 9 volt.
1. The battery is housed in a convenient battery drawer located in the faceplate of the Water Level Meter.
 2. To replace the battery, simply press the drawer in, lift then pull.
 3. The battery drawer should slide out of the faceplate enough to pull it out.
 4. Note the polarity (positive (+) terminal should be towards the small notch in the end of the drawer) and place new battery in the drawer and slide it back into the faceplate.

Replacement Parts

The following parts can be provided should they become lost or damaged.

1. Probes
2. Tape with Tape Seal Plug
3. Tape Seal Plug on shorter lengths of tape (3 ft or 1 m) and splice kit
4. Lights, switches, etc.
5. Reels

Troubleshooting

SYMPTOM	CAUSE	REMEDY
No sound when probe immersed in water.	Dead battery.	Replace with 9V Alkaline.
	Water Conductivity is very low.	Increase sensitivity switch setting (turn clockwise) or call Solinst for assistance.
	Disconnected wires on circuit board.	Check all connections inside hub of reel for loose/disconnected wires - solder or reconnect.
	Broken wire in tape.	Locate break in tape - splice and seal. (Contact Solinst)
	Disconnected wire inside probe.	Contact Solinst to obtain parts/repair instructions.
Instrument continuously sounds after being immersed in water.	Water in probe. Probe may be dirty which could interfere with the circuit connection.	Disconnect P7 Probe. If sounding stops, check/replace o-ring. If sounding continues, check connection of electronics and wiring in reel. If sounding continues, contact Solinst for assessment or replace probe with new P7 probe.

HERON H.OIL / WATER INTERFACE METER

Model: H.OIL
Length Options: 50Ft/15m to 1000ft/300m
Warranty: 5 years
Certified intrinsically safe to CSA/NRTL standards



THE H.OIL

The Heron H.OIL is certified intrinsically safe for use in explosive environments. Using the grounding cable ensures safety when working in hazardous environments. The H.OIL is a precision instrument used to accurately measure the thickness of product layers (LNAPL) as thin as 1 mm (1/200ft) floating on the water table and sinking layers (DNAPL) quickly, easily and accurately. The fully pressure proof probe is 5/8" (1.6cm) in diameter and is ideal for wells, piezometers and direct push equipment. The H.OIL will signal oil with a solid tone and light. The H.OIL will signal water with an intermittent tone and a flashing light.

H.OIL TAPE SPECIFICATIONS

The H.OIL uses the premium high tensile steel, easy read yellow tape jacketed in clear Kynar. The Kynar jacketing can withstand attack from hydrocarbons, solvents and other harsh contaminants. This accurate high strength engineering grade tape is manufactured to the ASME standard of accuracy. The flexible tape winds smoothly onto the tough Nylon reel while the dog-bone cross section prevents the tape from sticking to wet surfaces and well casings. The H.OIL tape is marked to engineering scale: Feet and tenths with markings every 1/100ft and Meters and Centimeters with markings every mm.

H.OIL ELECTRONIC MODULE SPECIFICATIONS

The H.OIL includes a fully potted, fully field removable electronic module. The super bright red LED and buzzer are housed inside this water tight module. The H.OIL works on one 9 volt battery in an easy access battery drawer mounted on the front of the module. This state of the art electronic module has an automatic shut off after 10 minutes, designed to extend the life of the battery.

H.OIL PROBE SPECIFICATIONS

The H.OIL comes with a standard 5/8" (1.6cm) diameter fully submersible, leak proof probe up to 1000ft/300m. The stainless steel probe is 7" (18cm) in length and is attached to the tape using a flexible linking device that allows the tape and probe to be protected at this vital junction. The lens at the end of the probe is protected by a stainless steel shield. The emitter at the tip sends a beam of infra red light through the lens to the detector. This process identifies conductive liquid (water) and non conductive liquid (product) to give the appropriate signal. The H.OIL probe is field replaceable.

H.OIL REEL SPECIFICATIONS

The H.OIL is a well balanced unit. The stand alone, sturdy steel frame is coated in Polyurethane for durability. The vinyl coated carry handle is ergonomically designed for comfort and easier rewinding. The reel flanges and center hub are molded from high strength Nylon running on a stainless steel axle allowing the smooth running of tape up and down the well or borehole. The third hand well casing hanger and tape guide are standard features on all Heron units. The H.OIL frame includes the grounding cable used for safety in explosive environments.

OBTAINING PRODUCT MEASUREMENTS WITH THE H.OIL

To obtain the measurement of the thickness of product floating on the surface of the water, lower the probe into the well until the tone and light signal liquid. If there is product present the electronic module will indicate with a solid tone and a solid light. Take your measurement by reading the tape at your datum point. Continue to lower the probe into the well, when the tone and light become intermittent you have encountered water. Pull the probe back up slowly taking your reading at the product/water interface. If no product is present in your well only the intermittent tone and light will signal. DNAPLS can be detected by continuing to lower the probe to the bottom of well noting any solid tone and light signals.

FEATURES TO REMEMBER

- Certified intrinsically safe to CSA/NRTL standards included.
- Yellow easy read flexible tensile steel tape manufactured to ASME standards included.
- Tape guide and third hand well casing hanger included.
- Hydrocarbon resistant Kynar jacketing on tape included.
- Durable padded carry case and cleaning kit included.

OPTIONS

- Heron field support kit



Water Level Meter

Model 101

For measuring the depth to water in wells, boreholes, standpipes, and tanks, Model 101 Water Level Meters are the industry standard for portable hand operated meters. They are sturdy, easy to use and read accurately to 1/100 ft. or each millimeter.

There are two versions to choose from. The Model 101 P7 Water Level Meter features a pressure-proof probe rated to 500 psi and laser marked PVDF tape. The Model 101 P2 Water Level Meter features an easy-to-repair probe and heat embossed polyethylene tape.

Also available, is the less expensive Model 102 Coaxial Cable Water Level Meter for use in small diameter tubes, and the 102M Mini Water Level Meter on a small, compact reel (see Model 102 Data Sheet).

Operating Principles

Model 101 Water Level Meters use corrosion proof stainless steel probes attached to permanently marked flat tape, fitted on a well-balanced reel. They are powered by a standard 9 volt battery.

The probes incorporate an insulating gap between electrodes. When contact is made with water, the circuit is completed, activating a loud buzzer and a light. The water level is then determined by taking a reading directly from the tape at the top of the well casing or borehole.

A sensitivity control allows the buzzer to be turned off while in cascading water, and ensures a clear signal in both high and low conductivity conditions.

Reels

With a stand-alone design, convenient carrying handle, and sturdy probe holder, the standard reels are ergonomically designed for ease of use. They are robust and smooth running. The battery is housed in a convenient drawer in the front of the reel, allowing quick replacement. The reels are equipped with an on/off sensitivity switch, light, buzzer, battery test button, brake and a tape guide stored on the frame.

P7 Probe

The P7 Probe is submersible up to 1000 ft. (300 m), ideal for measuring total well depth. The sensor at the tip of the probe provides consistent measurements with almost zero displacement. The tape seal plug design allows the probe to be quickly and easily replaced, if required.

Size: 5/8" dia., 5.38" long (16 mm x 137 mm)

Weight: ~4.5 ounces (128 g)



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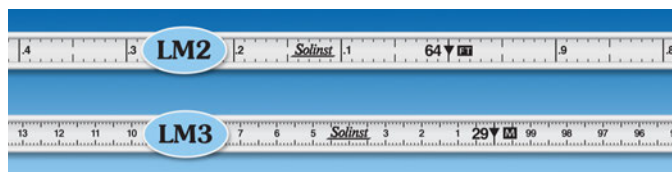
101 P7

PVDF Laser Marked Tape

The Model 101 P7 Water Level Meter uses extremely durable, PVDF flat tape, traceable to NIST and EU measurement standards. Each tape conductor contains 13 strands of stainless steel, and 6 strands of copper-coated steel, making the tape non-stretch and high in tensile strength and electrical efficiency. The tape has a thick dog bone design that prevents adherence to wet surfaces, and allows it to hang straight in application. It is also easy to splice. The 3/8" (10 mm) tape comes with permanent laser markings every 1/100 ft. or each millimeter, in lengths up to 5000 ft. (1500 m).

LM2: Feet and tenths: with markings every 1/100 ft.

LM3: Meters and centimeters: with markings every mm



Features

- Accurate:**
 - Markings each 1/100 ft. or millimeter
 - Traceable to national standards
 - Sensitivity adjustable to conductivity
 - Probes avoid false readings in cascading water
- Reliable:**
 - Permanent laser markings
 - Non-stretch PVDF tape with stainless steel conductors
- Long Life:**
 - Rugged, corrosion proof components
 - Strong, flexible tapes
 - Easy to splice and repair
- Flexible:**
 - PVDF replacement tapes are interchangeable with other meters



101 P2



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P2 Probe

The P2 Probe is shielded in design to reduce or eliminate false readings in cascading water. The probe consists of a stainless steel body with a neoprene heat shrink seal. It is not suitable for submergence to any significant depth. Its simple design makes it easy to repair.

Size: 0.55" dia., 7.5" long (14 mm x 190 mm)

Weight: ~7 ounces (200 g)



Zero Measurement Point

Polyethylene Tape

The Model 101 P2 Water Level Meter uses high quality polyethylene tape that reels smoothly, remains flexible and hangs straight in the well. Heat embossed marking each millimeter or 1/100 ft. allow accurate readings. The 3/8" (10 mm) wide tapes come in lengths up to 1000 ft. (300 m).

Seven stranded stainless steel conductors resist corrosion, provide strength and are non-stretch. They make the tape very easy to repair and splice. The dog-bone design reduces adherence to wet surfaces.

M2 Feet and tenths: with markings every 1/100 ft.

M3 Meters and centimeters: with markings every mm.



Length Options

Solinst Model 101 P7 and P2 Water Level Meters are available on reels as shown below, in the following standard lengths:

Small Reel	* 100 ft. 30 m	Medium Reel	* 500 ft. 150 m
	* 200 ft. 60 m		* 750 ft. 250 m
	* 300 ft. 100 m		* 1000 ft. 300 m
Large Reel			1250 ft. 400 m
			1650 ft. 500 m
			2000 ft. 600 m

* Polyethylene tapes are only available in these lengths



Model 101 Water Level Meter Reels



Other Options

Carrying Case: Small and medium padded nylon carrying cases are available, as an optional extra. Their design has a convenient shoulder strap, zippered front pocket, zippered top, and a grommet in the base to prevent moisture build-up.



Power Reels: Power reels can be very useful to allow faster or less strenuous operation of longer lengths of tape.

Replacement Parts: Replacement probes, tapes and other spare parts are available.

Tape Guide/Datum

A tape guide is provided with each Meter. It protects the tape from damage on rough edges of well casing and ensures easy, consistent measurements, regardless of who takes the readings. It can also provide support on the casing, for small reels.



Interface Meter

Model 122

Solinst Oil/Water Interface Meters give clear and accurate measurements of product level and thickness in wells and tanks.

Determination of both light (floating) non-aqueous phase liquids (LNAPL) and dense (sinking) non-aqueous phase liquids (DNAPL) is quick and easy. The factory-sealed probe is pressure proof (up to 500 psi) and tapes are available in a range of lengths from 100 - 1000 ft (30 - 300 m).

The 5/8" (16 mm) diameter probe allows easy access through tight spaces and into narrow wells. The probe is designed for use in various monitoring applications. 122M Mini Interface Meters also available, see 122M Data Sheet for more information.

Hazardous Locations Use

Model 122 Interface Meters have been approved for use in explosive environments. They are suitable for use in hazardous locations Class I, Div 1, Groups C&D based on standards of the Canadian Standards Association (CSA).

The Model 122 Interface Meter with laser marked PVDF tape is now ATEX certified under directive 94/9/EC, as II 3 G Ex ic IIB T4 Gc.

The grounding strap is a safety essential when the meter is used in potentially explosive environments. It also ensures that the electronics are properly protected.

Operating Principles

Product (Non-conductive liquid) = Steady light and tone

Water (Conductive liquid) = Intermittent light and tone

To detect liquids, Solinst Interface Meters use an infra-red beam and detector. When the probe enters a liquid the beam is refracted away from the detector which activates an audible tone and light.



If the liquid is a non-conductive oil/product the signals are steady. If the liquid is water (conductive liquid greater than 20 $\mu\text{S}/\text{cm}$), the conductivity of the water completes a conductivity circuit. This overrides the infra-red circuit, and the tone and light are intermittent.

The 122 Interface Meter sensor provides an accuracy as good as 1/200 ft or 1.0 mm. The high accuracy enables the sensor to detect the slightest sheen of oil on the surface of the water.



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Accurate, Reliable, Robust

- Designed for rugged field use
- Stable electronics with automatic circuitry testing
- Laser marked PVDF flat tape is easy to decontaminate; resists stains
- Tape uses stranded stainless steel and copper coated steel conductors:
 - high in tensile strength; electrical efficiency
 - non-stretch; does not corrode
- Sturdy free-standing reel with carrying handle

High Quality Design

The state-of-the-art electronics include automatic circuitry testing when the 'On' button is used; 120 hours of on-time battery life; clear signals; and high accuracy. The circuits are powered by a single standard 9V battery which is housed in an easy-access drawer in the faceplate of the reel.

Infra-red refraction is used to detect liquids and conductivity to distinguish water. Both optical and electronic sensors are precisely aligned at the same zero point. The factory sealed probe does not need to be accessed by the user. An integral stainless steel shield protects the sensors. It is set permanently into place, yet allows for easy cleaning.

Features

- Sensor accuracy to 1/200 ft or 1.0 mm
- Certified intrinsically safe
- 5/8" (16 mm) diameter probe
- Easy access 9V battery
- Automatic shut off after 10 minutes
- Easy to splice and repair
- Replacement tapes are interchangeable with other Meters

Model 122 is QPS approved for use in hazardous locations Class I, Div 1, Groups C&D based on CSA Standards and is ATEX certified under directive 94/9/EC as II 3 G Ex ic IIB T4 Gc

Obtaining Product Measurements

To measure the thickness of a product layer, lower the probe into the well until the signals activate. If there is an oil/product layer on the top of the water (LNAPL), the light and tone will be steady, indicating an air/product interface.

Read the depth off the permanently marked tape. Lower the probe further into the water, where the signals become intermittent, then pull back up and take a reading at the product/water interface. The thickness of the product layer is then determined by subtracting the first reading from the second.

P8 Probe

The 122 Interface Meter uses the P8 Probe, which is 5/8" (16 mm) in diameter and stainless steel. It is pressure proof, up to 500 psi. The beam is emitted from within a Hydex cone-shaped tip. The tip is protected by an integral stainless steel shield, and is excellent for the vast majority of product monitoring situations.



If there is only water in the well and no product, there will only be intermittent (water) signals. The presence or absence of dense (sinking) non-aqueous layers (DNAPL) is determined by continuing to lower the probe to the bottom of the well.

If the steady tone and light return, this indicates a non-conductive liquid. Measure the depth and continue lowering the probe until it touches bottom and the tape goes slack.

To determine the thickness of the DNAPL layer, subtract the first reading from the bottom depth.

Included Equipment

Each full size meter is provided with a grounding cable, cleaning brush, a convenient carrying case with shoulder strap, and a tape guide/datum.

The tape guide may be used to provide support for a small reel on the well casing. It acts as a datum allowing repeatably accurate measurements; ensures that the probe hangs in the centre of the well; and protects the tape from damage.

It is essential to use the grounding cable to ensure safety and proper function of the electronics in all applications.

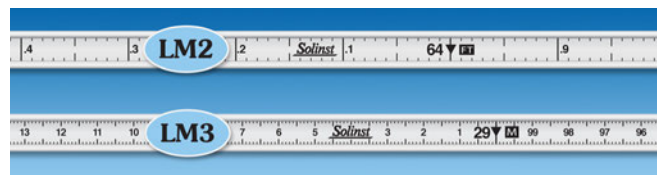
Laser Marked PVDF Flat Tape

The PVDF flat tape is extremely accurate, traceable to NIST and EU measurement standards.

The easy-to-read markings on the 3/8" (10 mm) PVDF flat tape are permanently laser-marked. The dog bone shaped tape avoids adherence to wet surfaces in wells. It is resistant to most chemicals, and the smooth surface of the tape is easy to decontaminate and easy to handle.

LM2: Feet and tenths: with markings every 1/100 ft.

LM3: Meters and centimeters: with markings every mm.



APPENDIX D



Y S I Environmental

YSI 556 Multiparameter System

Versatile, multiparameter handheld instrument

Rugged and reliable, the YSI 556 MPS (Multiprobe System) combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multiparameter system.



The 556 has multiple language capabilities and graphing!

- Simultaneously measures dissolved oxygen, pH, conductivity, temperature, and ORP
- Field-replaceable electrodes
- Compatible with EcoWatch® for Windows® data analysis software
- Stores over 49,000 data sets, time and date stamped, interval or manual logging
- Three-year warranty on the instrument; one-year on the probes
- GLP assisting, records calibration data in memory
- Available with 4, 10, and 20-m cable lengths
- IP-67, impact-resistant, waterproof case
- Easy-to-use, screw-on cap DO membranes
- RS-232 interface for PC connection

Options to Fit Your Applications!

- **Battery Options** – The unit is powered by alkaline batteries or an optional rechargeable battery pack with quick-charge feature.
- **Optional Barometer** – Internal barometer can be user-calibrated and displayed along with other data, used in dissolved oxygen calibrations, and logged to memory for tracking changes in barometric pressure. (Choose 556-02)
- **Optional Flow Cell** - The 5083 flow cell can be used for ground water applications or anytime water is pumped for sampling.
- **Carrying Case** – The instrument comes standard with YSI 5061, a soft-sided carrying case with enough space for the 556, a 20-meter cable, and calibrating supplies. An optional 5080 hard-sided carrying case is also available.
- **Confidence Solution®** - Quality assurance ensured. Quickly check conductivity, pH, and ORP readings with one solution.

Pure
Data for a
Healthy
Planet.®

*A rugged, cost-effective
multiparameter handheld
system designed for the field!*



+1 937 767 7241
800 897 4151 (US)
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YSI Environmental
+1 937 767 7241
Fax +1 937 767 9353
environmental@ysi.com

YSI Integrated Systems
+1 508 748 0366
systems@ysi.com

SonTek/YSI
+1 858 546 8327
inquiry@sontek.com

YSI Gulf Coast
+1 225 753 2650
environmental@ysi.com

AMJ Environmental
+1 727 565 2201
amj@ysi.com

YSI Hydrodata (UK)
+44 1462 673 581
europe@ysi.com

YSI Middle East (Bahrain)
+973 1753 6222
halsalem@ysi.com

YSI (Hong Kong) Limited
+852 2891 8154
hongkong@ysi.com

YSI (China) Limited
+86 532 575 3636
beijing@ysi-china.com.

YSI Nanotech (Japan)
+81 44 222 0009
nanotech@ysi.com

YSI India
+91 989 122 0639
sham@ysi.com

YSI Australia
+61 7 390 17223
acorbett@ysi.com

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Who's Minding
the Planet?™

5563 MPS Sensor Specifications

Dissolved Oxygen (% saturation)	Sensor Type Range Accuracy Resolution	Steady state polarographic 0 to 500% air saturation 0 to 200% air saturation, $\pm 2\%$ of the reading or $\pm 2\%$ air saturation, whichever is greater; 200 to 500% air saturation, $\pm 6\%$ of the reading 0.1% air saturation
Dissolved Oxygen (mg/L)	Sensor Type Range Accuracy Resolution	Steady state polarographic 0 to 50 mg/L 0 to 20 mg/L, $\pm 2\%$ of the reading or ± 0.2 mg/L, whichever is greater; 20 to 50 mg/L, $\pm 6\%$ of the reading 0.01 mg/L
Temperature	Sensor Type Range Accuracy Resolution	YSI Temperature Precision™ thermistor -5 to 45°C $\pm 0.15^\circ\text{C}$ 0.1°C
Conductivity	Sensor Type Range Accuracy Resolution	4-electrode cell with autoranging 0 to 200 mS/cm $\pm 0.5\%$ of reading or ± 0.001 mS/cm; whichever is greater (4-meter cable) $\pm 1.0\%$ of reading or ± 0.001 mS/cm; whichever is greater (20-meter cable) 0.001 mS/cm to 0.1 mS/cm (range-dependent)
Salinity	Sensor Type Range Accuracy Resolution	Calculated from conductivity and temperature 0 to 70 ppt $\pm 1.0\%$ of reading or ± 0.1 ppt, whichever is greater 0.01 ppt
pH (optional)	Sensor Type Range Accuracy Resolution	Glass combination electrode 0 to 14 units ± 0.2 units 0.01 units
ORP (optional)	Sensor Type Range Accuracy Resolution	Platinum button -999 to +999 mV ± 20 mV 0.1 mV
Total Dissolved Solids (TDS)	Sensor Type Range Resolution	Calculated from conductivity (variable constant, default 0.65) 0 to 100 g/L 4 digits
Barometer (optional)	Range Accuracy Resolution	500 to 800 mm Hg ± 3 mm Hg within $\pm 10^\circ\text{C}$ temperature range from calibration point 0.1 mm Hg

YSI 556 Instrument Specifications

Size	11.9 cm width x 22.9 cm length (4.7 in. x 9 in.)
Weight with batteries	2.1 lbs. (916 grams)
Power	4 alkaline C-cells; optional rechargeable pack
Cables	4-, 10-, and 20-m (13.1, 32.8, 65.6 ft.) lengths
Warranty	3-year instrument; 1-year probes and cables
Communication Port	RS-232 Serial
Data Logger	49,000 data sets, date and time stamp, manual or logging, with user-selectable intervals

556 Ordering Information (Order all items separately)

556-01	Instrument (with 5061 large, soft-sided carrying case)
556-02	Instrument with barometer option (with 5061 carrying case)
5563-4	4-m cable and DO/temp/conductivity
5563-10	10-m cable and DO/temp/conductivity
5563-20	20-m cable and DO/temp/conductivity
5564	pH Probe for any 5563 cable
5565	pH/ORP Probe for any 5563 cable
6118	Rechargeable battery pack kit (includes battery, adapter, charger)
614	Ultra clamp, C-clamp mount
616	Charger, cigarette lighter
4654	Tripod (small tripod for instrument)
5060	Small carrying case, soft-sided (fits instrument and 4-m cable)
5065	Form-fitted carrier with shoulder strap
5080	Small carrying case, hard-sided (fits instrument, 4-m cable, flow cell, batteries, membrane kit, calibration bottles)
5083	Flow cell
5085	Hands-free harness
5580	Confidence Solution® (insure probe accuracy with a simple field-check for conductivity, pH, and ORP)



The 5080 carrying case with 556, 5563-4 cable, and 5083 flow cell.

Peristaltic Sampling Pumps

Geopump™ Peristaltic Pumps

The Geotech Geopump™ Series I and II Peristaltic Pumps are designed for single and multi-stage pressure or vacuum pumping of liquids. They operate by mechanical peristalsis, so the sample only comes in contact with the tubing. This allows for consistent sample integrity as well as easy cleaning and replacement. The Geopump is ideally suited for field sample removal from shallow wells and all surface water sources or for laboratory use.

FEATURES

- Exceptional field durability
- Operate from 60 to 600 RPM
- Up to 1 liter/min. delivery rate
- Operate to a depth of 27 feet
- Variable speed control
- AC only, DC only, or an AC/DC combination
- Two pumping stations available, which can be piggybacked for multi-station pumping
- Reversible flow feature for back-flushing
- Disposable and dedicated tubing means controlled costs and no decontamination issues

OPERATION

The Geotech Peristaltic Pumps operate by mechanical peristalsis, so the sample only comes in contact with the tubing. This allows for sample integrity as well as easy cleaning and replacement. With the optional stainless steel tubing weight, tubing can be lowered to a specific depth without curling or floating on the surface of the water. Geopumps operate from any external 12V DC or 120V AC power source.

SERIES I Geopump™ Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. These units have one pumping station which can be piggy-backed for multi-station pumping. They have variable speeds ranging from 60 RPM to 350 RPM.

SERIES II Geopump™ Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. They have two pumping stations which can also be piggy-backed for multi-station pumping. The first pumping station has a variable speed of 30 to 300 RPM and the second station 60 to 600 RPM.



Geopump™ Peristaltic Pump Series II with Easy-Load 2 pump head (optional), modular battery, 5 ft. tubing, carrying case and power cord



Geopump™ Peristaltic Pump Series II with Easy-Load 2 pump head (optional) and dispos-a-filter™ capsule

CALL GEOTECH TODAY (800) 833-7958

Geotech Environmental Equipment, Inc.

2650 East 40th Avenue • Denver, Colorado 80205

(303) 320-4764 • (800) 833-7958 • FAX (303) 322-7242

email: sales@geotechenv.com website: www.geotechenv.com

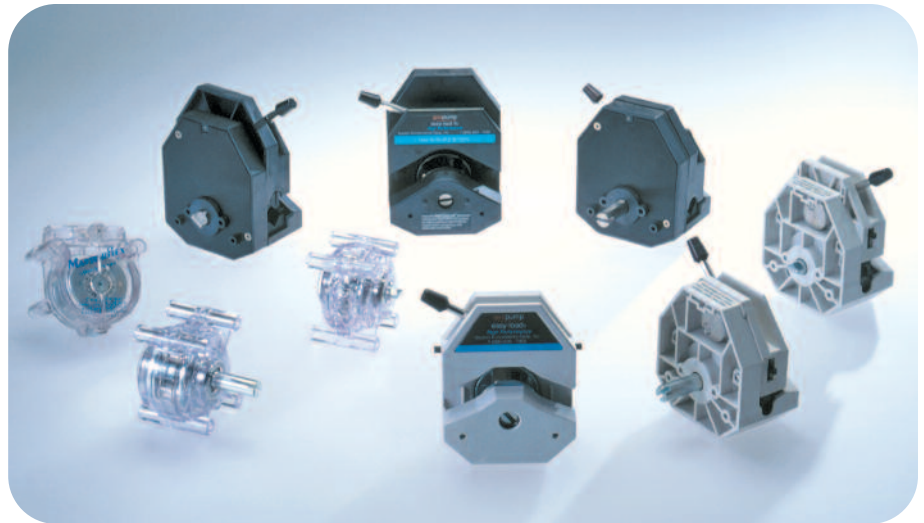
Peristaltic Sampling Pumps



Geopump™ Peristaltic Pumps

ACCESSORIES

- Quick Load pump head
- Easy Load pump head
- Silicone tubing
- Tygon tubing
- Other tubing
- Stainless steel tubing weight
- Custom length power cord
- Geotech Back Flushing Membrane Filter Holder
- Geotech in-line dispos-a-filter™ filter capsule
- Rechargeable battery
- Battery charger
- Optional stainless steel rotor for pump
- Additional power cords
- Carrying case



Geopump™ pump heads (easy-load, standard, quick load) shown with small and large shaft

SPECIFICATIONS

Operating Range	Suction from 27 feet at sea level
Principle of Operation	Mechanical peristalsis
Dimensions	3.5 x 8 x 8 inches
Power Source	Any external 12V DC or 120V AC
Power Cord	12V DC adapter cord or standard AC power cord
Power Cord Length:	AC Cord 8 feet DC Cord 15 feet
Range of Speed:	
Series I	60 to 350 rpm
Series II	First pumping station 30 to 300 rpm Second pumping station 60 to 600 rpm
Speed Control	Stepless variable speed control
Liquid Delivery Rate	1.67 ml per revolution
Pumping Options	Pressure or vacuum (reversible flow)
Pump Head Rotor	Cold rolled steel
Warranty	1 year
Basic System Kit	Geopump (as specified), 5ft. of tubing, power cord (as specified), field case, and manual
Pump Head (sold separately)	Standard, Easy-Load 1, Easy-Load 2, or Quick Load



Geopump™ Modular Battery and Charger



Geopump™ Tubing Weights

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Geopump Peristaltic Pump

Installation and Operation Manual



Rev. 4 9/14/09 Part # 81350020

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DOCUMENTATION CONVENTIONS

This uses the following conventions to present information:



An exclamation point icon indicates a **WARNING** of a situation or condition that could lead to personal injury or death. You should not proceed until you read and thoroughly understand the **WARNING** message.



A raised hand icon indicates **CAUTION** information that relates to a situation or condition that could lead to equipment malfunction or damage. You should not proceed until you read and thoroughly understand the **CAUTION** message.



A note icon indicates **NOTE** information. Notes provide additional or supplementary information about an activity or concept.

NOTICES



In order to ensure that your Controller has a long service life and operates properly, adhere to the cautions below and read this manual before use.

Disconnect from power source when not in use.

Controller power input source must not exceed maximum ratings

Controller must be wired to a negative ground system

Controller may not operate properly with excess wiring not supplied by manufacturer

Avoid spraying fluid directly at equipment

Never submerge equipment

Avoid pulling on wires to unplug equipment wiring

Avoid using equipment with obvious physical damage

To prevent equipment damage, avoid dropping it



The Geotech Geopump Peristaltic Pump cannot be made dangerous or unsafe as a result of failure due to EMC interference.



WARNING

Do not operate this equipment if it has visible signs of significant physical damage other than normal wear and tear.



Notice for consumers in Europe:

This symbol indicates that this product is to be collected separately.

The following apply only to users in European countries:

- This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste.
- For more information, contact the seller or the local authorities in charge of waste management.

Chapter 1: System Description

Function and Theory

The Geotech Series I and II Peristaltic Pumps are designed for single and multi-stage pressure or vacuum pumping of liquids for field or laboratory use. Since they operate to a depth of 27 feet at sea level, they are ideally suited for sample removal from shallow wells and all surface water sources. They operate by mechanical peristalsis, therefore the sample comes in contact only with the tubing. This allows for sample integrity as well as easy cleaning and tubing replacement. Tubing can be lowered to a specific depth without curling or floating on the surface of the water with use of optional stainless steel tubing weight. Differences between the two models affect the number of pump heads which may be used with the Geopump at one time, and the speed(s) at which the pump heads operate. Therefore, the instructions for general operations will be covered only once.

System Components

SERIES I Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. These units have one pumping station which can also be piggy-backed for multi-station pumping. They are variable speed from 60 RPM to 350 RPM.

SERIES II Peristaltic Pumps are available in AC only, DC only, or an AC/DC combination. They have two pumping stations which can also be piggy-backed. The first pumping station is rated at 30 RPM to 300 RPM and the second station at 60 RPM to 600 RPM. Each pumping station works in conjunction with the other.

Chapter 2: System Installation

Standard Pump Head Instructions

1. Separate pump halves. Hold the pump head as shown with the rollers in the 2, 6, and 10 o'clock positions and the rotor shaft facing down.



2. Place the tubing around the rollers.



3. Turn rotor counterclockwise until tubing has completely surrounded the rotor.
4. The tubing is now in place. Next, position other pump half onto the motor shaft and snap shut. Be careful not to pinch tubing between plastic halves.



Chapter 3: System Operation

The pump kit arrives packed in a hard shelled peristaltic pump carry case with the pump head properly attached to the pump (purchased separately). See section on pump parts.

To put into service:

1. Remove the pump from the case and be sure pump is turned "OFF" (red, open circle)
2. For AC/DC combination units, plug in the appropriate power cord into the outlet in the back of the pump & other end of the power cord into the power source.
3. Insert the tubing into the pump head.
4. Put one end of the tubing into the sample source (well, river, ditch, lagoon, etc.) and the other end into the sample container.
5. Determine the desired direction of flow and turn the direction toggle switch in that direction.
6. Turn the pump "ON" (the black filled circle).
7. Once pumping has begun, the speed dial can be adjusted to increase or reduce the fluid pumping speed, as desired.

Chapter 4: System Maintenance

Peristaltic Pump: Maintenance Tips

The Geotech Peristaltic Pump has a strong reputation for durability and being virtually maintenance free. These simple maintenance steps will assure your pump's long term reliability:

Pump Tubing:



Geotech recommends regular tubing replacement for optimum performance, using the proper size and type of tubing for the pump head is essential. If you are unsure of tubing type for your application, please call Geotech. Depending on the pump head design, different sizes of tubing may be used. Use of the incorrect tubing, size or type, will cause damage to the pump and/or the pump head and void the warranty.

Pump:

Keep your Geopump clean and dry. In the event that the Geopump is subjected to significant splashing or immersion, discontinue use and wipe the unit down immediately with a clean dry cloth.

- To keep your Geopump reliable follow these simple guidelines:
- Do not drop your Geopump
- Do not immerse your Geopump
- Do not subject your Geopump to poor power supplies
- Do not subject your Geopump to extreme heat or cold when in use

Power Cords:

Always replace any kinked or damaged power cord. Units with hard-wired power cords should be sent back to Geotech for proper repair (see pg. 12). However, replacement power cords are available for AD/DC combination units.

Pump Head:

Your Geopump pump-head needs to be periodically cleaned with a Phosphate - free cleaning detergent and water solution.

Chapter 5: System Troubleshooting

Problem: Unit will not turn on

Solution:

1. No power to unit:(rollers not moving)
 - Check power source and compatibility
 - Check connections
2. Speed control not set fast enough to overcome tubing resistance:
 - check speed setting; if too low turn it up
3. Check tubing size and type. Make sure it is the correct size and type for the pump head
4. Check circuit breaker; if tripped press it in to reset.

Problem: Unit turns on, but not pumping...(Pump head rollers are moving)

Solution:

1. Verify fluid level in well (max suction lift unit can pump from is 27' below ground at sea level).
2. Water level is below down well tubing intake-Increase tubing length.
3. If using a combination of flexible and rigid tubing check connection, between tubing. A poor connection may cause a vacuum leak. Secure tubing connection.
4. Flexible tubing in pump head compromised or worn out:
 - Replace flexible tubing regularly
5. Obstruction in tubing:
 - Check for clogs and kinks
 - Clear any obstructions
6. Using incorrect tubing type for pump head:
 - Tubing may be collapsed.
 - Replace with proper tubing type

Problem: Pump head rollers are not moving

Solution:

1. Pump head is loose from the pump housing:
 - Tighten pump head screws to engage pump head to gear.
 - Possible internal damage - call Geotech for consultation.

Chapter 6: System Specifications

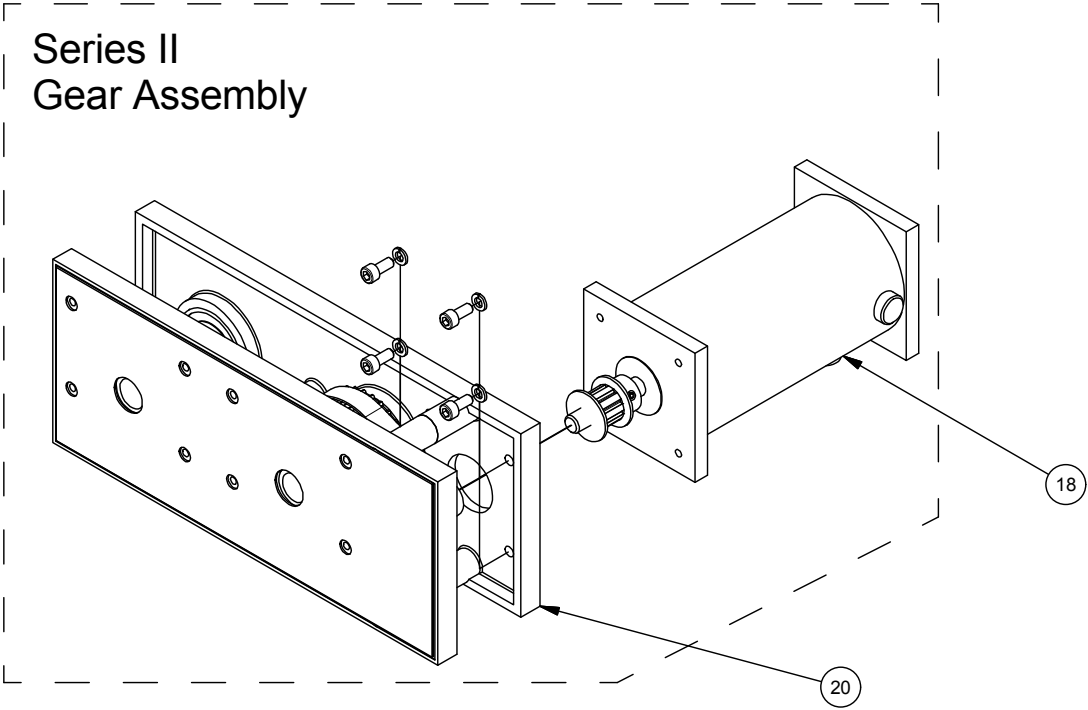
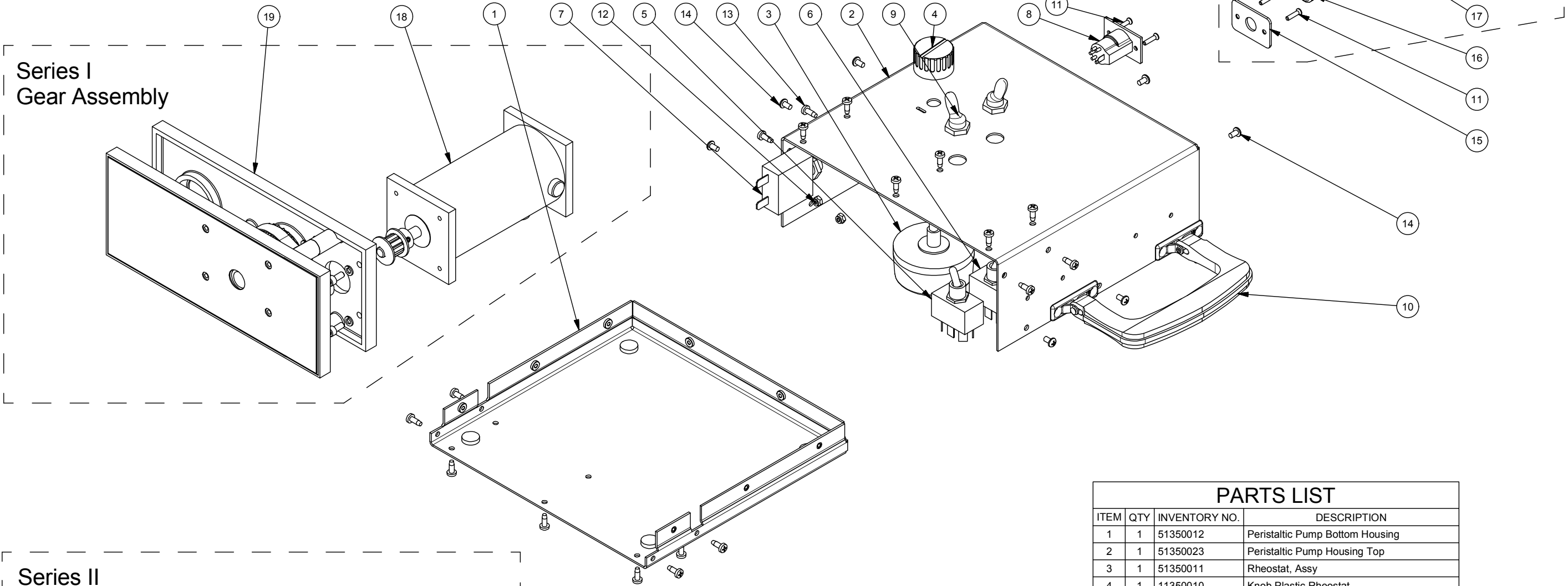
Operating range	27 feet at sea level
Principle of Operation	Mechanical peristalsis
Dimensions	3.5 x 8 x 8 inches
Power source	Any rated external 12-18 VDC @ 70 Watts
Nominal operating current	3 amps DC
Over current Protection	5 amps DC
Power cord	12 VDC cord.
Range of speed: Series I	60 to 350 RPM
Range of speed: Series II	First pumping station 30 to 300 RPM Second pumping station 60 to 600 RPM
Speed control	Stepless variable speed control
Liquid delivery rate	1.67 ml per revolution (for size 15 tubing)
Pumping options	Pressure or vacuum (reversible flow)
Pump head rotor	Cold rolled steel

OPTIONS

Models:	Geopump 1, Geopump 2
Tubing:	Silicone, Tygon, Viton, C-Flex
Pump Heads:	Standard, Easyload, Quickload

Chapter 7: System Schematic

DC Power Only



PARTS LIST			
ITEM	QTY	INVENTORY NO.	DESCRIPTION
1	1	51350012	Peristaltic Pump Bottom Housing
2	1	51350023	Peristaltic Pump Housing Top
3	1	51350011	Rheostat, Assy
4	1	11350010	Knob Plastic Rheostat
5	1	11350020	Switch Toggle DPDT Forward-Reverse
6	1	11350021	Switch Toggle DPST ON-OFF
7	1	11350005	Breaker Thermal 5A Circuit
8	1	51350004	Wiring Harness Assy
9	2	17500037	Boot Rubber Toggle Switch Grey
10	1	11350009	HANDLE, PE, NI
11	2	17200076	4-40 x 1/2 FHMS
12	2	17200046	4-40 Nylock Nut
13	20	17200077	6-32X3/8 SS Self Tapping Machine Screw
14	8	17200078	6-32 X 1/4 SS PHMS
15	1	11350015	Aluminum Plate for DC Only
16	1	11350019	Rubber Grommet
17	1	17500040	DC Power Cable
18	1	51350003	Replacement Motor Assembly
19	1	51350001	Series I - Replacement Gear Assembly
20	1	51350002	Series II - Replacement Gear Assembly

Chapter 8: Replacement Parts List

Parts Number	Part Description
17500035	Adaptor, Cigarette to Clips
51350030	Power Supply AC adapter
57500008	Assy, Power Cord, DC (AC/DC Unit)
51350001	Assy, Gear Housing, Series I
51350002	Assy, Gear Housing, Series II
51350012	Assy, Housing, Bottom, PP
51350003	Assy, Motor, PP
51350011	Assy, Rheostat
51350004	Assy, Wiring Harness, PP
17500037	Boot, RBR, Toggle Switch Grey
11350005	Breaker, Thermal, 5amp, Circuit 250V
51350015	Case, Peristaltic Pump with foam
51350026	Faceplate, Gear Hsng, Series I Aluminum
51350025	Faceplate, Gear Hsng, Series II Aluminum
17500042	Foot, Rubber, 9/32 Hole DIA
17200079	F, Screw, Short, Peristaltic Pump SS8, 8-32X1.25, filter
17200199	F, Screw, Thumb, Peristaltic Pump 8-32X2.5, ZN
71350030	F, Screw, Ezload II Pumphead Long Shaft
11350009	Handle, PE, NI
51350023	Housing, Top, Slk, Scrn
11350010	Knob, Plastic, Rheostat
11350020	Switch, Toggle, Dpdt, Frwd/Rvrs
11350021	Switch, Toggle, Dpst, On/Off

Old Style Non CE parts

Parts Number	Part Description
57500007	Assy, Power Cord, AC
51350007	Assy, Diode, PP
57500009	Assy, Rectifier Bridge, PP-Logic
51350013	Assy, Transformer, PP

The Warranty

For a period of one (1) year from date of first sale, product is warranted to be free from defects in materials and workmanship. Geotech agrees to repair or replace, at Geotech's option, the portion proving defective, or at our option to refund the purchase price thereof. Geotech will have no warranty obligation if the product is subjected to abnormal operating conditions, accident, abuse, misuse, unauthorized modification, alteration, repair, or replacement of wear parts. User assumes all other risk, if any, including the risk of injury, loss, or damage, direct or consequential, arising out of the use, misuse, or inability to use this product. User agrees to use, maintain and install product in accordance with recommendations and instructions. User is responsible for transportation charges connected to the repair or replacement of product under this warranty.

Equipment Return Policy

A Return Material Authorization number (RMA #) is required prior to return of any equipment to our facilities, please call 800 number for appropriate location. An RMA # will be issued upon receipt of your request to return equipment, which should include reasons for the return. Your return shipment to us must have this RMA # clearly marked on the outside of the package. Proof of date of purchase is required for processing of all warranty requests.

This policy applies to both equipment sales and repair orders.

FOR A RETURN MATERIAL AUTHORIZATION, PLEASE CALL OUR SERVICE DEPARTMENT AT 1-800-833-7958 OR 1-800-275-5325.

Model Number: _____

Serial Number: _____

Date: _____

Equipment Decontamination

Prior to return, all equipment must be thoroughly cleaned and decontaminated. Please make note on RMA form, the use of equipment, contaminants equipment was exposed to, and decontamination solutions/methods used. Geotech reserves the right to refuse any equipment not properly decontaminated. Geotech may also choose to decontaminate equipment for a fee, which will be applied to the repair order invoice.

Declaration of Conformity
Geotech Environmental Equipment Inc.
2650 E 40th Avenue
Denver, CO 80205
Following products are covered:
Geotech product
PN

These products comply with the directive 2004/108/EC (EMC),
harmonized standard EN 61010-1 2001-12-07, emissions class A.
These products comply with harmonized standard EN 61326-1 May 2006.

Signatory:

Joe Leonard



Product Development

Year of manufacture:

EMC conformity established 8/14/2009.

This declaration is issued under the sole responsibility of Geotech
Environmental Equipment Inc.

Model _____

Serial number _____



Geotech Environmental Equipment, Inc 2650 East 40th Avenue Denver,
Colorado 80205 (303) 320-4764 • **(800) 833-7958** • FAX (303) 322-7242 email:
sales@geotechenv.com website: www.geotechenv.com

In the EU

Geotech Equipos Ambientales S.L.
Abat Escarré # 12 Mollet del Valles, Barcelona 08100, España
Tlf: **93 5445937**
email: international@geotechenv.com website: www.geotechenv.com/spain.html
Printed in the United States of America

Rev. 8/15/09 Part # 11150263



YSI 556 Multi-probe System

Rugged and reliable, the YSI 556 MPS water quality analyser (Multi probe system) combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multi-parameter system. Featuring an IP-67, impact resistant case, the YSI 556 MPS simultaneously measures dissolved oxygen, pH, conductivity, salinity, temperature and ORP. This monitor designed for water quality applications is used mainly in the environmental industry and rents with 10m and 20m cable and Flow Cell.

Key Features

Field-replacable DO electrode modules; pH and pH/ORP probes

Compatible with Ecowatch for Windows data analysis software

Easy-to-use, screw-on cap DO membranes

Available with a 10m cable

Stores over 49,000 data sets, time and date stamped

Technical Specifications

Title	Value
Dissolved Oxygen (% saturation)	
	Sensor Type - Steady state polarographic
	Range - 0 to 500% air saturation
	Accuracy - 0 to 200% air saturation, $\pm 2\%$ of the reading or 2% air saturation, whichever is greater; 200 to 500% air saturation, $\pm 6\%$ of the reading
	Resolution - 0.1% air saturation
Dissolved Oxygen (mg/L)	
	Sensor Type - Steady state polarographic
	Range - 0 to 50mg/L
	Accuracy - 0 to 20mg/L, $\pm 2\%$ of the reading or 0.2mg/L whichever is greater; 20 to 50mg/L, $\pm 6\%$ of the reading
	Resolution - 0.01mg/L
Temperature	
	Sensor Type - YSI Precision thermistor
	Range: -5 to 45°C
	Accuracy - $\pm 0.15^\circ\text{C}$
	Resolution - 0.1°C
Conductivity	
	Sensor Type - 4-electrode cell with autoranging
	Range - 0 to 100 mS/cm
	Accuracy - $\pm 0.5\%$ of reading + 0.001 mS/cm
	Resolution - 0.001 mS/cm to 0.1 mS/cm (range-dependant)
Salinity	
	Sensor Type - Calculated from conductivity and temperature
	Range - 0 to 70 ppt
	Accuracy - $\pm 1.0\%$ of reading or 0.1 ppt, whichever is greater
	Resolution - 0.01 ppt
pH	
	Sensor Type - Glass combination electrode
	Range - 0 to 14 units
	Accuracy - ± 0.2 units
	Resolution - 0.01 units
ORP	
	Sensor Type - Platinum button
	Range - -999 to +999mV
	Accuracy - ± 20 mV
	Resolution - 0.1 mV
Barometer	

Dimensions

Title	(mm)	(inch)	(kg)	(lbs)
W x L	119mm x 229mm	4.7" x 9"	0.91 kg	2.1 lbs

APPENDIX E



First
Environmental
Laboratories, Inc.

1600 Shore Road, Suite D
Naperville, IL 60563
Phone: (630)778-1200 * Fax (630)778-1233
E-Mail: info@firstenv.com
IEPA Accreditation #100292

CHAIN OF CUSTODY RECORD

Company Name:			
Street Address:			
City:		State:	Zip:
Phone:	Fax:	e-Mail:	
Send Report To:		Via Fax: <input type="checkbox"/>	Via e-Mail: <input type="checkbox"/>
Sampled By:			

Project I.D.: _____ P.O. #: _____												Enter analyses required on the lines to the left. Place an "X" in the box below to indicate which samples require what analysis.	
Date/Time Taken	Sample Description	Matrix											Comments

FOR LAB USE ONLY:

Cooler Temperature:0.1-6°C Yes___ No___ °C
Received within 6 hrs of collection:_____
Ice Present: Yes___ No___

Sample Refrigerated: Yes___ No___
Refrigerator Temperature:____ °C

Containers Received Preserved: Yes___ No___
5035 Vials Frozen: Yes___ No___
Freezer Temperature:____ °C

Notes and Special Instructions:			
Relinquished By:	Date/Time:	Received By:	Date/Time:
Relinquished By:	Date/Time:	Received By:	Date/Time:

Section A

Section B

Section C

Required Client Information:		Report To:		Required Client Information:		Report To:		Required Client Information:		Report To:	
Company		Address		P.O.		Project Name:		Project Number:		Project Manager:	
Phone		Fax		*TAT:		*Turn around time less than 14 days subject to laboratory and contractual obligations and may result in a Rush Turnaround Surcharge.		Requested Analysis:		Remarks / Lab ID	
Address		P.O.		Project Name:		Project Number:		Requested Analysis:		Remarks / Lab ID	
Phone		Fax		*TAT:		*Turn around time less than 14 days subject to laboratory and contractual obligations and may result in a Rush Turnaround Surcharge.		Requested Analysis:		Remarks / Lab ID	
Address		P.O.		Project Name:		Project Number:		Requested Analysis:		Remarks / Lab ID	
Phone		Fax		*TAT:		*Turn around time less than 14 days subject to laboratory and contractual obligations and may result in a Rush Turnaround Surcharge.		Requested Analysis:		Remarks / Lab ID	

ITEM #	Section D		Required Client Information:		Valid Matrix Codes MATRIX DRINKING WATER GROUNDWATER SURFACE WATER WASTE WATER PRODUCT SOIL OIL WPE AIR OTHER		CODE DW GW SW WW P SL VIP AIR OT		MATRIX CODE		SAMPLE TYPE G=GRAB C=COMP		COLLECTED				SAMPLE TEMP AT COLLECTION		Preservatives Unpreserved H2SO4 HNO3 HCl NaOH Na2S2O3 Methanol Other																				Remarks / Lab ID																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Pace Analytical®

CUSTODY SEAL

SIGNATURE _____

DATE _____



Pace Analytical®

www.pacelabs.com

Client: _____

Client Sample ID: _____

Date Collected: _____ Time: _____

Collected by: _____

Analysis: _____

Preservative: ☐ None ☐ HNO₃ ☐ H₂SO₄ ☐ NaOH ☐ HCl

☐ Na₂S₂O₃ ☐ MeOH ☐ Zn Acetate ☐ Other: _____

APPENDIX F

GROUNDWATER SAMPLING INFORMATION FORM

Project:	Route 113 Release	Field Personnel:	
Date:		Comments:	
Weather			
Conditions:			

PURGE DATA:

[illegible]

SAMPLE COLLECTION DATA:

[illegible]

SAMPLE INFORMATION:

[illegible]

APPENDIX G



AIR MONITORING / SAMPLING WORK PLAN

Prepared For:

Wood River Pipelines, LLC

Route 113 Release

Kankakee, Illinois

DISCLAIMER:

SOME FORMATTING CHANGES MAY HAVE OCCURRED WHEN
THE ORIGINAL DOCUMENT WAS PRINTED TO PDF; HOWEVER,
THE ORIGINAL CONTENT REMAINS UNCHANGED.

MARCH 17, 2014
(REPLACES WORK PLAN FOR MARCH 14, 2014)

Prepared by:
Conestoga-Rovers
& Associates

11719 Hinson Road, Suite 100
Little Rock, AR
United States 72212

Office: (501) 224-1926
Fax: (501) 224-2313

web: <http://www.CRAworld.com>

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1.0 INTRODUCTION AND OBJECTIVES

Conestoga Rovers & Associates (CRA) will provide air monitoring and industrial hygiene support in potentially impacted areas along a section of pipeline located near Kankakee, Illinois (Route 113 and Indian Trail Road). These services are provided to evaluate potential health concerns pertaining to a petroleum pipeline release that was reported on March 14, 2014. The contents of the pipeline were reported to be, “gasoline, diesel, and/or gasoline/diesel mixture”. This pipeline is operated by Wood River Pipe Lines, LLC (Wood River). The initial assessment indicated that approximately ten barrels of product were released from the pipeline.

The purpose of this work plan is to address air monitoring / sampling during the response and mitigation phases of the project. The specific objectives include the following:

- Perform real-time air monitoring for volatile organic compounds (VOC) at the perimeter of the work site to characterize potential exposures to members of the community.
- Perform real-time air monitoring for volatile organic compounds (VOC) in areas off-site (i.e. residential areas, businesses, etc.) to evaluate potential exposure to off-site receptors.
- Perform real-time air monitoring for VOCs in the breathing zones of workers to evaluate potential exposures during on-site activities.
- Collect personal air samples, i.e. worker breathing zone samples, for petroleum constituents, i.e. benzene, toluene, ethyl benzene, xylene (BTEX), naphthalene, and total hydrocarbons during on-site operations.
- Collect area air samples petroleum constituents (i.e. BTEX, naphthalene, and total hydrocarbons, etc.) along the site perimeter and at off-site location as necessary to evaluate off-site exposures.
- Evaluate off-site health complaints and fugitive odors to determine potential risks.
- Comply with the air monitoring requirements of the applicable Occupational Safety and Health Administration (OSHA) Benzene Standards.
- Establish and implement procedures to ensure appropriate responses to elevated levels of gasoline/diesel compounds. This may include identifying areas requiring respiratory protection, or arranging for a timely evacuation of the work site in the event that hazardous concentrations of airborne BTEX vapors are detected.
- Communicate the hazards associated with exposures to gasoline/diesel constituents to the affected workers, members of the neighboring community, and other potential receptors.
- Provide recommendations for controlling site exposures, respiratory protection and other personal protective equipment (PPE) to incident command.

- Otherwise evaluate the health hazards associated with the response and mitigation phases of the project.

CRA will continue monitoring until the clean up phase of the project is completed and worker / community exposures to gasoline/diesel are eliminated. The air monitoring data will be collected and compiled in accordance with established guidelines. In addition, the results will be communicated to Wood River, site workers, and others as required and/or as necessary to ensure the safety and health of potentially affected individuals.

2.0 EXPOSURE STANDARDS AND GUIDELINES

CRA will rely on the standards and guidelines established in the United States for affected workers and community members. The air monitoring / sampling results, collected at the Site, will be compared to the applicable occupational exposure limits (OEL), Minimal Risk Levels (MRL), and other applicable guidelines, such as the United States Environmental Protection Agency's (USEPA) Regional Screening Levels (RSLs) for residential receptors. CRA will also consider the parameters of the facility's air permitting requirements as part of the preparation for this assessment.

Occupational Exposure Limits

Federal OSHA promulgates workplace standards to protect the safety and health of workers. OSHA requires the employer to reduce airborne exposures below the established permissible exposure limits (PEL). Additionally, the American Conference of Governmental Industrial Hygienists (ACGIH) has established threshold limit values (TLV) to protect workers from hazards on the job. The established TLVs shall be considered guidelines in the control of health hazards. Similarly, the National Institute for Occupational Safety and Health (NIOSH) has established guidelines to protect workers from chemical hazards on the job. Table 1 summarizes the OSHA permissible exposure limits (PEL), ACGIH threshold limit values (TLV), and NIOSH Immediately Dangerous to Life and Health (IDLH) guidelines for the recognized chemicals of interest (COI) identified at the response site.

Table 1
Occupational Exposure Limits and Guidelines

<i>Analyte</i>	<i>OSHA PEL</i>		<i>ACGIH-TLV</i>		<i>NIOSH-IDLH ⁵</i>	<i>Units</i>
	TWA ¹	STEL ²	TWA ³	STEL ⁴		
Benzene	1	5	0.5	2.5	500	ppm
Tolulene	200	300 C ⁶	20	---	500	
Ethyl Benzene	100	125	100	125	800	
Xylene	100	150	100	150	900	

1. Permissible Exposure Limit - Time Weighted Average (PEL-TWA) = An 8-hour time weighted average. An exposure to any material listed in 29 CFR 1910.1000, Tables Z1 and Z2, in any 8-hour work shift of a 40-hour workweek shall not exceed the 8-hour time weighted average limit given for that material in the table.
2. Permissible Exposure Limit - Short Term Exposure Limit (PEL-STEL) = A 15 minute TWA exposure that should not be exceeded at any time during a workday.
3. Threshold Limit Value - Time Weighted Average (TLV-TWA) = The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect (ACGIH, 2014).
4. Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) = A 15 minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA. (ACGIH, 2014)
5. Immediately Dangerous to Life and Health (IDLH) = Indicates an exposure to airborne contaminants that is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.
6. Acceptable Ceiling = An exposure to a substance listed in OSHA Table Z-2 shall not exceed at any time during an 8-hour shift the acceptable ceiling concentration given for the substance in the table, except for a time period and up to a concentration not exceeding the maximum duration and concentration allowed in the column under "acceptable maximum peak" above the acceptable ceiling concentration for an 8-hour shift

Community Risk Levels

The Agency for Toxic Substances & Disease Registry (ATSDR) has developed Minimal Risk Levels (MRLs) to serve as a screening tool for public health professionals to evaluate potential exposure to hazardous substances. MRLs are estimates of the daily exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. MRLs are derived for acute (1-14 days), intermediate (>14-364 days), and chronic (≥365 days) exposure durations. ATSDR uses the no observed adverse effect level/uncertainty factor (NOAEL/UF) approach to derive MRLs. They are set below levels that, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. Exposure to a level above the MRL does not mean that adverse health effects will occur. Due to the potential acute health effects associated with

exposures, analytical results will be compared to the applicable MRL. These values for the identified COI with established MRLs for inhalation exposures are summarized in Table 2.

Table 2
ATSDR Minimal Risk Levels (Inhalation)

<i>Compound of Interest</i>	<i>Acute</i>	<i>Intermediate</i>	<i>Chronic</i>	<i>Units</i>
Benzene	0.009	0.006	0.003	ppm
Toluene	1	---	0.08	
Ethylbenzene	5	2	0.06	
Xylene	2	0.6	0.05	

The MRL-based screening of air data is a screening-level evaluation known as Tier 1. Further evaluations comparing air monitoring data to site-specific and duration-specific exposure values is known as Tier 2. USEPA's Acute Exposure Guideline Levels (AEGLs) will be used as guidance to prevent unnecessary exposure to residents under the Tier 2 approach. The AEGL-1 values for the COI are listed in Table 3. The AEGL-1 values are defined as:

“The airborne concentration (expressed as ppm [parts per million] or mg/m³ [milligrams per cubic meter]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.”

Table 3
USEPA Acute Exposure Guideline Levels (Inhalation)

<i>Compound of Interest</i>		<i>Exposure Duration</i>				
		<i>10 min</i>	<i>30 min</i>	<i>60 min</i>	<i>4 hr</i>	<i>8 hr</i>
Benzene	AEGL-1	130	73	52	18	9
Toluene	AEGL-1	200	200	200	200	200
Ethylbenzene	AEGL-1	33	33	33	33	33
Xylene	AEGL-1	130	130	130	130	130

Based on these levels, site-specific action levels for the community are summarized in Table 3. Benzene is the COI primarily considered for the site-specific action levels due to the fact it possesses the lowest guideline. Based on evaluations to-date, the ratio of benzene air concentrations to total VOC air concentrations is approximately 1:100. Thus, a reading of 10 ppm VOC indicates the presence of approximately 0.1 ppm benzene. The action levels for benzene will be guided by the real-time air concentration of total VOCs using this relationship. Real-time air monitoring for benzene will be performed when appropriate to characterize areas with known airborne VOCs. CRA personnel will immediately report any exceedances of the AEGL-1 values to Jason Wernsman, Mac Meade, or Chad Koranda.

Response Action Levels

Action levels have been established to facilitate a timely and appropriate response to the detection of airborne hazards associated with COI. Action levels have been set at levels lower than the established exposure limits and guidelines. The purpose is to ensure that if these levels are detected, they are effectively communicated to affected workers and off-site receptors so that appropriate action can be taken. The action levels were established based on the information provided for the Site. These action levels may be modified as additional information on the Site conditions becomes available. The site-specific action levels for the work site are listed in Table 4.

Table 4
Real Time Air Monitoring Site Action Levels

<i>Analyte</i>	<i>Action Level ¹</i>	<i>Description of Action</i>
Benzene	<0.25 ppm	No action required.
	≥0.25 ppm	Confirm with a duplicate sample. Benzene levels will be communicated to designated site officials (Jason Wernsman, Mac Meade, or Chad Koranda) and workers will be notified to move away from the area
Toluene	< 50 ppm	No action required.
	50-100 ppm	Confirm with a duplicate sample. Toluene levels will be communicated to designated site officials (Jason Wernsman, Mac Meade, or Chad Koranda).
	> 100ppm	Confirm with a duplicate sample. Workers will be notified and moved away from areas of elevated concentrations.
Xylene	< 50 ppm	No action required.
	50-100 ppm	Confirm with a duplicate sample. Xylene levels will be communicated to designated site officials (Jason Wernsman, Mac Meade, or Chad Koranda).
	>100 ppm	Confirm with a duplicate sample. Workers will be notified and moved away from areas of elevated concentrations.
VOCs	< 25 ppm	No action required.
	25-50 ppm	VOC levels will be communicated to designated site representatives (Jason Wernsman, Mac Meade, or Chad Koranda). Confirm benzene levels using chemical-specific detection method.
	> 50 ppm	Confirm with duplicate sample. Workers will be notified and moved away from areas of elevated concentrations.

1. Action Levels are based on sustained (>1 min) airborne concentrations.

3.0 REAL-TIME MONITORING

Real-time air monitoring for VOCs will be performed during normal work operations using RAE Systems MultiRAE Plus Photoionization Detectors (PID) AreaRAE PIDs, and UltraRAE PIDs, with benzene-specific detection tubes. The MultiRAE and AreaRAE instrument detection limit for VOCs is 0.1 ppm and the UltraRAE instrument detection limit for benzene is 0.1 ppm. In addition, Gastec colormetric detection tubes will be used to monitoring for specific COI (i.e.

BTEX). All instruments will be calibrated and operated in accordance with the manufacturer's specifications or applicable test/method specifications. Real time air monitoring will be performed at the following locations:

- Impacted areas where workers are present
- Site perimeter – upwind and downwind
- Off-site receptors (as identified and appropriate)

AreaRAE PIDs will be placed at the perimeter of the work site and programmed to continuously monitor VOC concentrations. Using radio telemetry, the instantaneous readings for each AreaRAE will be transmitted to a single host computer at the site, allowing CRA personnel to simultaneously monitor the airborne concentrations for all perimeter stations from a central location. AreaRAE PID instruments will be deployed as necessary along the site perimeters and at off-site locations to evaluate potential exposures during response and mitigation activities. It is anticipated that the AreaRAE monitoring locations will change based on site conditions (i.e. changes in wind direction). To ensure adequate air monitoring aerial maps will be generated for all area monitoring locations and communicated with project management. MultiRAE and UltraRAE PIDs as well as Gastec detector tubes will be used to monitor the airborne concentrations of VOCs and BTEX in the immediate work area and at designated off-site locations. A schedule for periodic air monitoring inside the potentially affected areas will be generated and implemented as necessary to evaluate these exposures.

If airborne concentrations of the chemicals listed in Table 4 are detected above the action levels established for the site, designated site safety personnel, operations officials, affected workers, and/or local regulatory representatives will be notified and appropriate actions will be taken to ensure the health and safety of the site workers. Table 5 shows correction factors for the COI on real-time instruments. In addition, a comparison of instrument readings and the chemical-specific OSHA PEL is provided.

Table 5
Real-time Monitoring Instruments Correction Factors

<i>Chemical</i>	<i>Correction Factor</i>	<i>OSHA PEL</i>	<i>VOC reading indicating potential exceedance of the PEL</i>
Benzene	0.53	1 ppm	1.9 ppm
Ethylbenzene	0.52	100 ppm	192 ppm
Toluene	0.5	200 ppm	400 ppm
Xylene	0.46*	100 ppm	217 ppm

*maximum of o-, m-, and p-xylene

4.0 INTEGRATED AIR SAMPLING

Personal air samples will be collected from the breathing zones of on-site workers in order to evaluate potential exposures to constituents of gasoline/diesel. These air samples will be analyzed for BTEX, naphthalene, and total hydrocarbons.

A similar exposure group (SEG) analysis will be conducted to determine the number of samples which should be collected to represent the various job tasks conducted during the clean up efforts. SEGs are groups of workers having the same general exposure profile because of the similarities and frequency of the tasks they perform, the materials/processes in which they work, and the similarity of the way they perform the tasks. CRA personnel will identify and continuously observe work activities with potential gasoline/diesel exposures to determine SEGs. The major processes and work operations will be defined and correlated with the potential exposure to gasoline/diesel based on proximity to impacted areas. The number and frequency of personal air samples will be determined by the CRA CIH based on the representative exposures of the on-Site workers.

Area air samples for BTEX naphthalene, and total hydrocarbons will be collected along the perimeter of the Site for comparison to the applicable community risk based standards for the Site COI. The area sample stations will be co-located with the real-time air monitoring instruments. These samples will be collected in order to determine representative airborne exposures during response and mitigation activities. The frequency and duration of the area air sampling will be determined by a CRA CIH, based on the recognized risk to off-Site receptors.

All samples will be collected and analyzed in accordance with established methods. The analytical air sampling methods for constituents of gasoline/diesel are summarized in Table 6, and copies of these methods are included as attachments.

Table 6
Summary of Analytical Air Sampling Methods

<i>Analytical Method</i>	<i>Sample Media</i>	<i>Flow Rate (mL/min)</i>	<i>Typical Sample Volume</i>
NIOSH 1500/1501	100mg / 50 mg charcoal tube, w/ air sampling pump	200	96L
	3M 3520 OVM Passive Dosimeter	N/A	N/A
EPA TO15+TICs	1 Liter Mini-Can	---	1L

All samples will be shipped daily to Galson Laboratories, an American Industrial Hygiene Association (AIHA) accredited laboratory. Media will be provided to the laboratory for field blank sample comparison. All samples will be shipped using appropriate Chain of Custody (COC) procedures. Laboratory turnaround times (TAT) for analysis will be determined by the on-site CRA Project Manager.

5.0 QUALITY ASSURANCE / QUALITY CONTROL (QA/QC) AND REPORTING

All real-time air monitoring / integrated air sampling data and supporting documentation collected during this project will be stored in a comprehensive on-site electronic database. CRA will utilize a custom database application that will upload data directly to a secure CRA server, which will be backed up daily. CRA and approved users will have unlimited access to view current and historical photographs, sampling / survey information, reports, and other supporting documentation collected in real-time through a secure CRA website. CRA will utilize mobile data collection and data management tools for field data collection, archiving, and reporting.

CRA utilizes industry-leading mobile data collection and data management tools for field data collection, archiving, and reporting. Hardware such as iPads and ruggedized mobile devices will be used during the survey in order to increase the accuracy of the data collected and decrease the reporting time.

All manually-collected real-time data and integrated sampling information will be reviewed to ensure accuracy and completeness. The manually-collected monitoring / sampling data will be uploaded into an electronic database and will undergo a daily QA/QC review. All data entry forms and field notes will be kept on-site and retained for reference upon completion of the project. Any errors identified during the QA/QC process in field notes or data will be noted appropriately, while retaining original information to ensure a proper historical record. If necessary, full laboratory analysis data packages will be provided, and associated data validation processes will be arranged.

During the project, interim reporting of results may be required. This may include data summaries, maps, or other presentations of preliminary monitoring and sampling results. Such reporting will be considered preliminary, as a final QA/QC of the data will not be complete. At the completion of the project, a report will be prepared in which all data collected through real-time monitoring and integrated sampling analyses will be compiled, summarized, and reported to Wood River. All data contained in the final report will have been through the QA/QC

process, will be reviewed by a CRA CIH, and will be considered final. On site workers will also be notified of sampling results in accordance with applicable OSHA regulations.

This work plan was prepared by:

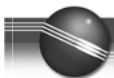


Benjamin Chandler, M.S., CIH
Conestoga-Rovers & Associates

This work plan was reviewed by:



Joe Cameron
Conestoga-Rovers & Associates



Sensor Specifications And Cross-Sensitivities

Note: All performance specifications are subject to change without notice and are based upon conditions at 68°F (20°C), 50% relative humidity and 1 atm (1013 mBar). See

the glossary on the last page for definitions of the specifications.

Combustibles (LEL)

Sensor Type:	Protected catalytic bead
Gases detected:	Most combustible gases & vapors
Range:	0-100% LEL
Resolution:	1% LEL
Response Time (t₉₀):	30 sec.
Bias & Equilibration:	No bias; 10 min after installation
Drift:	<10% LEL/month
Storage Life:	2 years in sealed container
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	50% LEL of Methane, or 2.5% by volume, balance air

Response Data LEL

Please see TN-156 for cross sensitivity data, this document is the primary source for such data with respect to the LEL sensor.

Oxygen (O₂)

Sensor Type:	Electrochemical
Range:	0 to 30%
Resolution:	0.1%
Response Time (t₉₀):	15 sec.
Bias & Equilibration:	No bias; 10 min after installation
Temp Range:	5° F to 104° F (-15° C to +40° C)
Pressure Range:	Atmospheric ± 10%
Operating Humidity:	0 to 99% non condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	Ambient air (20.9% oxygen)
Zero Gas:	99.9% N ₂

Note: Measurements can be made in pure ethylene; recovery to ambient air may require a few hours.

Ammonia (NH₃) P/N: 008-1118-000

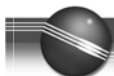
Sensor Type:	Electrochemical
Range:	0 to 50 ppm *
Max Overload:	200 ppm *
Resolution:	1 ppm
Response Time (t₉₀):	150 sec
Bias & Equilibration:	Bias on; 6 hrs. after installation
Temp Range:	-31° F to 86° F (-25° C to 30° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15 to 90% non-condensing
Drift:	< 10% signal loss/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	1 year in air
Warranty:	1 year from date of shipment
Calibration Gas:	50 ppm NH ₃ , balance N ₂
Calibration flow rate:	1000 cc/min. for 3 min.

Cross-sensitivity Data NH₃

Gas	Conc.	Response
Triethylamine	50 ppm	25 ppm
CO	300 ppm	0 ppm
H ₂ S	15 ppm	about 15 ppm
SO ₂	5 ppm	about 3 ppm
NO	35 ppm	about 7 ppm
NO ₂	5 ppm	0 ppm
Cl ₂	1 ppm	about -0.5 ppm
H ₂	100 ppm	0 ppm
HCN	10 ppm	about 0.5 ppm
HCl	5 ppm	0 ppm
Hydrazine		3:1
Ethylene	100 ppm	0 ppm

* Consumable Iodine reagent sensor.

- To be discontinued in 2008 Units affected: VRAE, MultiRAE+, QRAE+, and AreaRAE



Ammonia (NH₃) – P/N: 008-1125-000

Sensor Type:	Electrochemical
Range:	0-100 ppm *
Max Overload:	100 ppm *
Resolution:	1 ppm
Response Time (t₉₀):	60 sec
Bias & Equilibration:	No Bias; 10 min after installation
Temp Range:	-4° F to 104° F (-20° C to 40° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	<2% signal loss/month
Storage Life:	1 year in sealed container
Storage Temp:	-20° C to +40° C
Operating Life:	2 year in air
Warranty:	1 year from date of shipment
Calibration Gas:	50 ppm NH ₃ , balance N ₂
Calibration flow rate:	1000 cc/min for 3 min

* Short gas exposure of ~60 seconds.

- Available for VRAE, MultiRAE+, and QRAE+ in 2008.

Carbon Dioxide (CO₂)

Sensor Type:	Non-dispersive infrared (NDIR)
Range:	0-50,000 ppm (0-5 vol%)
Resolution:	10 ppm
Response Time (t₉₀):	60 sec
Bias & Equilibration:	No Bias; 10 min after installation
Temp Range:	-4° F to 122° F (-20° C to 50° C)
Pressure Range:	Atmospheric ±20%
Operating Humidity:	5-95% non-condensing
Drift:	<5% signal/month
Storage Life:	2 years in sealed container
Storage Temp:	-40° F to 122° F (-40° C to 50° C)
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	5000 ppm CO ₂ , balance air
Calibration flow rate:	500 cc/min for 2 min.

Cross-sensitivity Data CO₂

Gas	Conc.	Response
CH ₄	25,000 ppm	<20 ppm
Ethane	10,000 ppm	<20 ppm
Ethylene	13,500 ppm	<20 ppm
Acetylene	12,500 ppm	<20 ppm
Propane	10,000 ppm	<20 ppm
Acetone	10,000 ppm	<20 ppm
Carbon disulfide	10,000 ppm	<20 ppm

Carbon Monoxide (CO)

Sensor Type:	Electrochemical
Range:	0-500 ppm
Max Overload:	1500 ppm
Resolution:	1 ppm
Response Time (t₉₀):	35 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	<2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	50 ppm CO, balance air
Calibration flow rate:	150 cc/min

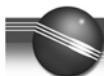
New sensor. Used sensors show increasing response to VOCs.

See Technical Note 121 for more information.

* Disk-shaped activated carbon fiber filters (p/n 008-3006-005) placed on top of the CO sensor help reduce response to VOCs

Cross-sensitivity Data CO

Gas	Conc.	Response w/o Filter#	Response w/ Filter*
H ₂ S	10 ppm	0 ppm	
SO ₂	5 ppm	0 ppm	
Cl ₂	10 ppm	0-1 ppm	
HCl	10 ppm	0 ppm	
NO	35 ppm	1 ppm	1 ppm
NO ₂	5 ppm	0 ppm	0 ppm
NH ₃	100 ppm	0 ppm	0 ppm
H ₂	100 ppm	40 ppm	40 ppm
Ethylene	100 ppm	24 ppm	20 ppm
Acetylene	250 ppm	250 ppm	
Ethanol	200 ppm	0 ppm	0 ppm
Ethylene oxide	125 ppm	≥40 ppm	
Propane	100 ppm	0 ppm	0 ppm
Butane	100 ppm	1 ppm	1 ppm
Isobutylene	100 ppm	9 ppm	4 ppm
Isobutylene	1000 ppm	30 ppm	22 ppm
Hexane	500 ppm	0 ppm	0 ppm
MEK	100 ppm	0 ppm	0 ppm
TCE	100 ppm	25 ppm	15 ppm
Nitrogen	100 %	0-4 ppm	



Carbon Monoxide (CO) High Range

Sensor Type:	Electrochemical
Range:	0-2000 ppm
Resolution:	10 ppm
Response Time (t₉₀):	35 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4 °F to 122°F (-20°C to 50°C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	<2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	200 ppm CO, balance air
Calibration flow rate:	500 cc/min

New sensor. Used sensors show increasing response to VOCs.
See Technical Note 121 for more information.

* Disk-shaped activated carbon fiber filters (p/n 008-3006-005) placed on top of the CO sensor help reduce response to VOCs

Cross-sensitivity Data CO High Range

r/c

Gas	Conc.	Response w/o Filter#	
H ₂ S	15 ppm	0 ppm	
SO ₂	5 ppm	0 ppm	
Cl ₂	10 ppm	0-1 ppm	
NO	35 ppm	-10-0 ppm	
NO ₂	5 ppm	0 ppm	
H ₂	100 ppm	<50 ppm	
Ethylene	100 ppm	<30 ppm	
Ethanol	200 ppm	0 ppm	

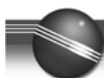
Chlorine (Cl₂)

Sensor Type:	Electrochemical
Range:	0 to 50 ppm
Resolution:	0.1 ppm
Response Time (t₉₀):	30 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 104° F (-20° C to 40° C)
Temperature Effect:	no effect on sensitivity or zero
Pressure Range:	Atmospheric ±10%
Operating Humidity:	5 to 95% non-condensing
Drift:	< 10% signal/six months
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	10 ppm Cl ₂ , balance N ₂
Calibration flow rate:	1,000 cc/min. for 2 min.

Cross-sensitivity Data Cl₂

s

Gas	Conc.	Response
NH ₃	65 ppm	0
CO	300 ppm	0
CO ₂	10%	0
H ₂ S	10 ppm	-0.3 ppm
SO ₂	5 ppm	-1.2 ppm
NO	35 ppm	<3 ppm
NO ₂	5 ppm	0.1 ppm
N ₂	100%	0
H ₂	1000 ppm	0
HCN	10 ppm	0
HCl	20 ppm	0
Br ₂	1 ppm	1 ppm
ClO ₂	0.32 ppm	0.3 ppm
Ethanol	6.6%	0
Hydrocarbons	% Range	0



Chlorine Dioxide (ClO₂)

Sensor Type:	Electrochemical
Range:	0 to 1 ppm
Resolution:	0.01 ppm
Response Time (t₉₀):	120 sec.
Bias & Equilibration:	Bias off; 10 min. after installation
Temp Range:	-4° F to 104° F (-20° C to 40° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	5 to 95% non-condensing; no effect
Drift:	< 5% signal/six months
Effect of Temperature:	<0.02 ppm increase from -4° F to 122° F (-20° C to 50° C)
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	0.50 ppm ClO ₂ from gas generator or equivalent of 1.25 ppm Cl ₂
Calibration flow rate:	1,000 cc/min. for 2.5 min.. Requires on-site ClO ₂ gas generator, Cl ₂ surrogate gas, or quarterly factory calibration

Cross-sensitivity Data ClO₂

Gas	Conc.	Response
Cl ₂	1 ppm	0 ppm*
Cl ₂	1 ppm	0.4 ppm [#]
ClF ₃	1 ppm	1 (theor.) ppm
O ₃	0.1 ppm	0.03 ppm
H ₂ S	10 ppm	0 ppm*
H ₂ S	25 ppm	-1.1 ppm [#]
SO ₂	5 ppm	0 ppm [#]
CO	1000 ppm	0 ppm
CO	50 ppm	0 ppm [#]
CO ₂	5000 ppm	0 ppm
HCl	5 ppm	0 ppm
HF	3 ppm	0 ppm
H ₂	10,000 ppm	0 ppm
NH ₃	50 ppm	0 ppm [#]
PH ₃	300 ppm	0.3 ppm
AsH ₃	1 ppm	0.8 ppm
HCN	10 ppm	0 ppm
H ₂ Se	0.1 ppm	0 ppm
NO	25 ppm	0.9 ppm [#]
NO ₂	5 ppm	1.5 to 2.3 ppm [#]
Chloropicrin	100 ppm	0 ppm [#]
Hydrocarbons	% range	0 %
Alcohols	1000 ppm	0 ppm

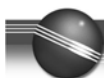
* Short exposure of <few minutes of <100 ppm, with filters

[#] Onboard filters removed.

Notes on ClO₂ sensor calibration and operation:

ClO₂ sensors require a ClO₂ generator for calibration because this gas is too unstable to store in a cylinder. ClO₂ sensors may contain a built-in filter that removes Cl₂ and therefore cannot be calibrated using Cl₂ surrogate gas when the filter is present. ClO₂ sensors without the filter may be calibrated using a Cl₂ surrogate gas. NO₂ is not a reliable surrogate whether filter is present or not. This sensor should not be exposed to H₂S, which plugs the on-board filter, unless the filter is absent.

Caution: ClO₂ sensors without the on-board filter have a negative cross-sensitivity to H₂S and other reducing gases, and may underestimate the ClO₂ concentration if H₂S is present.



Hydrogen Chloride (HCl)

Sensor Type:	Electrochemical
Range:	0-15 ppm
Max Overload:	20 ppm
Resolution:	0.1 ppm (0.3 ppm threshold)
Response Time (t_{90}):	180 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 104° F (-20° C to +40° C)
Pressure Range:	Atmospheric $\pm 10\%$
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal loss/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	1 year in air
Warranty:	1 year from date of shipment
Calibration Gas:	10 ppm HCl, balance N ₂
Calibration flow rate:	500 cc/min for 4 minutes
Regulator:	Corrosion resistant

Cross-sensitivity Data HCl

Gas	Conc.	Response
Acetic acid	100 ppm	Yes
SO ₂	20 ppm	16 ppm
Cl ₂	1 ppm	0.7 ppm
CO	100 ppm	0 ppm
CO ₂	5000 ppm	0 ppm
H ₂	3000 ppm	<1 ppm
Alcohols	1000 ppm	0 ppm
Hydrocarbons	% range	0 ppm
HF	6 ppm	10 ppm
HNO ₃	1997 ppm	10.0 ppm

*Short exposure of a few minutes

Hydrogen Cyanide (HCN)

Sensor Type:	Electrochemical
Range:	0-50 ppm
Max Overload:	100 ppm
Resolution:	1 ppm
Response Time (t_{90}):	200 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 122° F (-20° C to +50° C)
Pressure Range:	Atmospheric $\pm 10\%$
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal loss/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	10 ppm HCN, balance N ₂
Calibration flow rate:	1000 cc/min

Cross-sensitivity Data HCN

Gas	Conc.	Response
CO	300 ppm	about 0.5 ppm
H ₂ S	15 ppm	see note below
SO ₂	5 ppm	~8 ppm
NO	35 ppm	about 3.5 ppm
NO ₂	5 ppm	about -10 ppm
H ₂	200 ppm	0 ppm
Ethylene	100 ppm	about 1 ppm

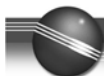
Due to a very high cross-sensitivity to H₂S, this sensor is unsuitable for use in atmospheres that contain H₂S.

Hydrogen Fluoride (HF)

Sensor Type:	Electrochemical
Range:	0-10 ppm
Max Overload:	20 ppm
Resolution:	0.1 ppm
Response Time (t_{90}):	20 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 104° F (-20° C to 40° C)
Pressure Range:	Atmospheric $\pm 10\%$
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	1 year in air
Warranty:	1 year from date of shipment
Calibration Gas:	10 ppm HCl, balance N ₂ (set span value to 6 ppm)
Calibration flow rate:	500 cc/min for 4 min
Regulator:	Corrosion resistant

Cross-sensitivity Data HF

Gas	Conc.	Response
Acetic acid	100 ppm	yes
SO ₂	20 ppm	16 ppm
Cl ₂	1 ppm	0.7 ppm
CO	100 ppm	0 ppm
CO ₂	5000 ppm	0 ppm
H ₂	3000 ppm	<1 ppm
Alcohols	1000 ppm	0 ppm
Hydrocarbons	% range	0 ppm
HCl	10 ppm	6 ppm



Hydrogen Sulfide (H₂S)

Sensor Type:	Electrochemical
Range:	0-100 ppm
Max Overload:	500 ppm
Resolution:	1 ppm
Response Time (t₉₀):	30 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	2 years from date of shipment
Calibration Gas:	10 ppm H ₂ S, balance N ₂

Cross-sensitivity Data H₂S

Gas	Conc.	Response
CO	300 ppm	≤1.5 ppm
SO ₂	5 ppm	about 1 ppm
NO	35 ppm	<0.7 ppm
NO ₂	5 ppm	about -1 ppm
H ₂	3000 ppm	0 ppm
HCN	10 ppm	0 ppm
HCl	10 ppm	0 ppm
NH ₃	50 ppm	0 ppm
PH ₃	5 ppm	about 4 ppm
CS ₂	100 ppm	0 ppm
Methyl sulfide	100 ppm	9 ppm
Ethyl sulfide	100 ppm	10 ppm*
Methyl mercaptan	5 ppm	about 2 ppm
Ethylene	100 ppm	≤ 0.2 ppm
Isobutylene	100 ppm	0 ppm
Toluene	10000 ppm	0 ppm*
Turpentine	3000 ppm	about 70 ppm*

Note: High levels of polar organic compounds including alcohols, ketones, and amines give a negative response.

*Estimated from similar sensors.

Nitric Oxide (NO)

Sensor Type:	Electrochemical
Range:	0-250 ppm
Max Overload:	1000 ppm
Resolution:	1 ppm
Response Time (t₉₀):	20 sec
Bias & Equilibration:	Bias on; 6 hr after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ± 10%
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	25 ppm NO, balance N ₂
Calibration flow rate:	250 cc/min

Cross-sensitivity Data NO

Gas	Conc.	Response
CO	300 ppm	0 ppm
SO ₂	5 ppm	0 ppm
H ₂ S	25 ppm	2 - 9 ppm
ClO ₂	1 ppm	-0.2 ppm
NH ₃	50 ppm	0 ppm
NO ₂	5 ppm	about 0.5 ppm
HCl	10 ppm	about 0.5 ppm
HNO ₃	1997 ppm	13.2 ppm

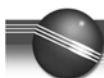
Nitrogen Dioxide (NO₂)

Sensor Type:	Electrochemical
Range:	0-20 ppm
Max Overload:	150 ppm
Resolution:	0.1 ppm
Response Time (t₉₀):	25 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	5 ppm NO ₂ , balance air
Calibration flow rate:	400 cc/min

Cross-sensitivity Data NO₂

Gas	Conc.	Response
NO	25 ppm	2.2 ppm
NH ₃	50 ppm	-0.2 ppm*
CO	50 ppm	-0.2 ppm*
CO	300 ppm	15 ppm
H ₂ S	25 ppm	-2.2 ppm
SO ₂	5 ppm	0 ppm
HCl	10 ppm	0 ppm
Cl ₂	1 ppm	-1 ppm
ClO ₂	1 ppm	-2 ppm
HNO ₃	1997 ppm	12.1 ppm

* Causes a transient drop upon exposure to this compound.



Phosphine (PH₃)

Sensor Type:	Electrochemical
Range:	0-5 ppm
Max Overload:	20 ppm
Resolution:	0.1 ppm
Response Time (t₉₀):	< 60 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	< 10% signal loss/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	1 year in air
Warranty:	1 year from date of shipment
Calibration Gas:	5 ppm PH ₃ , balance N ₂
Calibration flow rate:	1000 cc/min

Cross-sensitivity Data PH₃

c

Gas	Conc.	Response
Arsine	150 ppb	0 ppb
Arsine	2000 ppb	1200 ppb*
Silane	1000 ppb	900 ppb
Diborane	300 ppb	105 ppb
Germane	600 ppb	510 ppb
NH ₃	100 ppm	0 ppm
NO	100 ppm	0 ppm
SO ₂	5 ppm	1 ppm
CO	1000 ppm	1 ppm
CO ₂	50000 ppm	0 ppm
H ₂	1000 ppm	30 ppm
H ₂ S	25 ppm	5 ppm
HCN	10 ppm	0.6 ppm
HCl	10 ppm	0.2 ppm
Methane	50000 ppm	0 ppm
Ethylene	100 ppm	1.8 ppm
Isobutylene	250 ppm	0 ppm
Hexane, n-	1500 ppm	0 ppm
Benzene	100 ppm	0 ppm
Toluene	100 ppm	0 ppm
Ethylene oxide	10 ppm	0 ppm
CF ₂ Cl ₂	100 ppm	0 ppm
Chloroform	Headspace	0 ppm
Trichloroethylene	Headspace	<0.3 ppm

* Response after 9 minutes exposure. CF = 1.7 average, tested in range 500 to 3000 ppb AsH₃.

Sulfur Dioxide (SO₂)

Sensor Type:	Electrochemical
Range:	0-20 ppm
Max Overload:	150 ppm
Resolution:	0.1 ppm
Response Time (t₉₀):	15 sec
Bias & Equilibration:	Bias off; 10 min after installation
Temp Range:	-4° F to 113° F (-20° C to 45° C)
Pressure Range:	Atmospheric ±10%
Operating Humidity:	15-90% non-condensing
Drift:	< 2% signal/month
Storage Life:	6 months in sealed container
Storage Temp:	32° F to 68° F (0° C to 20° C)
Operating Life:	2 years in air
Warranty:	1 year from date of shipment
Calibration Gas:	5 ppm SO ₂ , balance N ₂
Calibration flow rate:	400 cc/min

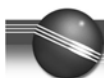
Cross-sensitivity Data SO₂

c

Gas	Conc.	Response
CO	50 ppm	0.3 ppm
CO	300 ppm	<3 ppm
CO ₂	1.5%	0 ppm
CS ₂	20 ppm	0.3 ppm
CS ₂	2000 ppm	14 ppm
H ₂ S	15 ppm	0 ppm
H ₂ S	250 ppm	0.3 ppm
H ₂ SO ₄	saturated	0 ppm
NH ₃	100 ppm	0 ppm
NO	25 ppm	≤ -2 ppm*
NO ₂	5 ppm	about -5 ppm
HCl	10 ppm	0 ppm
ClO ₂	0.5 ppm	≤ -2 ppm*
HF	70 ppm	0 ppm
Acetylene	10 ppm	1 ppm
Acetylene	100 ppm	10 ppm
Toluene	100 ppm	0 ppm
Isobutylene	100 ppm	0.4 ppm
1,3-Butadiene	5 ppm	4.3 ppm [#]
Styrene	200 ppm	>40 ppm [#]

* More negative than -2 ppm

[#] Cannot be removed by activated carbon because of SO₂ loss



Sensor Accuracies

Sensor accuracies depend on many factors including temperature, pressure, proper calibration, age of the sensor, and the presence of interferences. The values listed below apply to standard calibration gases within one day of calibration under the same environmental conditions. The accuracy limitation is always the greater of the two choices. For example, for the CO sensor, below 20 ppm the error is 2 ppm and above 20 ppm the error is 10% of the reading (e.g., 5 ppm @ 50 ppm).

Sensor	Estimated Accuracy
LEL	±3% LEL or 10% of Reading
TC	±5 Vol % or 15% of Reading
O ₂	±0.4 Vol % or 2% of Reading
CO ₂	±100 ppm or 10% of Reading <10,000 ppm ± 15% of Reading >10,000 ppm
CO	±2 ppm or 10% of Reading
CO HR	±5 ppm or 10% of Reading
HF	±0.5 ppm or 15% of Reading
H ₂ S	±2 ppm or 10% of Reading
SO ₂	±0.3 ppm or 10% of Reading
NO	±2 ppm or 10% of Reading
NO ₂	±0.3 ppm or 10% of Reading
HCN	±2 ppm or 10% of Reading
HCl	±0.5 ppm or 15% of Reading
Cl ₂	±0.5 ppm or 10% of Reading
ClO ₂	±0.1 ppm or 10% of Reading
NH ₃	±3 ppm or 10% of Reading
PH ₃	±0.3 ppm or 10% of Reading

Sensor Cross-Sensitivities

Electrochemical sensors, like many other sensors, are known to have cross-sensitivity to gases other than its target gas. Depending on the nature of the reaction in the sensor, the gas can either decrease the signal (negative cross-sensitivity) or increase the signal (positive cross-sensitivity). The cross

sensitivity data listed here are based on at most a few batches of electrochemical sensors. The actual values may vary between batches because the cross sensitivity is not typically controlled during the manufacturing process.

For safety concerns, a negative cross-sensitivity may present more risk than a positive one, as it will diminish the response to the target gas and so prevent an alarm. When calibrating a multi-gas sensor that has two sensors whose gas have significant cross-sensitivity, be sure to allow adequate time between calibrations to allow the sensors to clear.

When calibrating sensors with cross-sensitivities, calibrate the most cross-sensitive first, followed by the least cross-sensitive, wait for both sensors to recover to zero, and then expose both to gas again with most cross sensitive first and least cross sensitive second. For example, 50 ppm of NH₃ produces 0 ppm response on a Cl₂ sensor and 1 ppm of Cl₂ produces about -0.5 ppm of response on a NH₃ sensor. So calibrate the NH₃ sensor first with 50 ppm of NH₃. This should have no affect on the Cl₂ sensor. Then calibrate the Cl₂ sensor on 10 ppm Cl₂. This will send the NH₃ sensor negative for some period of time. After calibrating the Cl₂ sensor, return the meter to clean air and wait until the most cross-sensitive sensor (NH₃) fully recovers and/or stabilizes (if it stabilizes to a number other than zero then re-zero the meter). After both sensors return to zero apply calibration gas in the same order (NH₃ first then Cl₂) and note the sensor response. If both sensors are within 10% of the value on the gas cylinder then the calibration of the cross-sensitive sensors was successful.

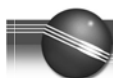
Use extreme caution with mixtures of gases!

The following table and data are based on % cross-sensitivity of a multi-sensor gas monitor to a single gas (for the sensor calibration time, at 0% relative humidity). Mixtures of the gases were not tested and results with mixed gases are unpredictable.

Cross-sensitivity table for selecting sensors for RAE Monitors:	
*	Slight sensitivity (<10% reading of the specified gas)
**	Moderate sensitivity (10 - 50% reading of the specified gas)
***	High sensitivity (>50% reading of the specified gas)
nd	No data
blank	No cross-sensitivity

		S E N S O R S											
		CO	HF	H ₂ S	SO ₂	HCN	Cl ₂	PH ₃	NH ₃	NO	NO ₂	ClO ₂	HCl
G A S	CO		*								*		
	HF				***		***						***
	H ₂ S	*	**			***	*	**	***	**	**	\$	**
	SO ₂	*	***	**		***		**	***	*	*	*	***
	HCN	nd	nd	*	**			*	*	nd	nd	nd	***
	Cl ₂		***	*	*	***		nd	***	*	***	**	***
	PH ₃	*	nd	**	**	***	nd		***	nd	nd	nd	
	NH ₃		**				*				*		**
	NO	*	*	*	*	*		nd	**		*	*	*
	NO ₂		***	**	***	***	**	nd	*	**		**	**
	ClO ₂	nd	nd	nd	***	nd	***	nd	nd	**	***		nd
	HCl		***		***		***						

\$ H₂S can be used with the ClO₂ sensor only if the on-board filter is removed



Extended Calibration Times

Some RAE Systems instruments incorporating electrochemical or NDIR sensors have a fixed calibration time (typically 60 seconds). This time accommodates most sensors, but a few have longer response times. In these cases, it is necessary to apply the calibration gas before starting the 60 to second automatic calibration step. The table below summarizes the recommended pre-exposure times.

Sensor	t_{90} (sec)	Total Calibration Time (sec)	Pre-exposure Time (sec)
HCN	200	230	170
PH ₃	60	120	60
NH ₃	60	180	120
HCl	90	180	120
HF	90	180	120
Cl ₂	30	120	90
ClO ₂	120	150	90
CO ₂	60	120	45 (std cal. time is 75 s)

Some RAE instruments do not recognize the presence of calibration gas when a flow is started before the "Apply Gas Now..." prompt, giving a warning, "No gas..." In this case, simply push the [Y/+] key to initiate the calibration.

Glossary

Range: The normal operating concentration of a sensor where the best linearity is found. Exceeding the normal operating range may result in erroneous readings and long recovery times, but should not permanently damage the sensor as long as the Max Overload is not exceeded.

Max Overload: The maximum exposure concentration. Exceeding this value will likely give erroneous readings and cause permanent damage to the sensor. This can be viewed as the sensor IDLH. Ammonia sensors often fail because they have been exposed to over 200 to 300 ppm (see Application Note AP-201).

Resolution: The least significant digit on the display or the minimum amount of chemical that the sensor can "see," (also known as: "Increment of measurement").

Response Time (t_{90}): The time for a sensor to reach 90% of its final stable reading. Typically an exposure of twice the t_{90} time is required to get a stable reading.

Bias & Equilibration: Some electrochemical sensors (NO, NH₃) require a bias voltage to detect the gas, while most do not. Unbiased sensors are shipped with a shorting pin across the electrodes to avoid an accidental bias. The pin should be removed before installation. Biased sensors require an equilibration time (also known as: warm-up time) of about 6 hours after installation for the baseline to become stable enough to calibrate the sensor. Unbiased sensors require only about 10 minutes to stabilize. Once installed, any sensor bias stays on, even when the meter is off. Therefore, even biased sensors are ready for immediate use when the instrument is turned on again, and the equilibration time is needed only when first installed or if the battery becomes completely drained. The SensorRAE can be used to maintain bias on NO and NH₃ sensors, and thus avoid

long equilibration times when swapping these sensors into a multi-gas instrument.

Temp Range: The normal operating temperature of the sensor. Sensors embody physico-chemical processes, which slow down when cooled and speed up when heated. Storing and using detectors outside in the winter may provide low readings if not recalibrated at the temperature of use. Storing detectors in hot cars in the summer may provide high readings and even dry out the sensors. Allowing a meter to return to normal operating temperature typically restores readings.

Pressure Range: The normal operating pressure of the sensor, typically atmospheric (14.7 psia) $\pm 10\%$. Some sensors have a transient response to sudden pressure changes, which may cause them to go into alarm for a short time.

Operating Humidity: Normal operating humidity. Typically 15 to 90% relative humidity, "non-condensing." Condensing humidity blocks the diffusion pathway, lowering the reading, and consistently high humidity can dilute the electrolyte and cause the cell to burst. Running or storing for extended periods in <10% RH gas can dry out the electrolyte and make the sensor inoperable.

Drift: The amount the sensor output may change over long time periods, expressed in %.

Storage Life: The recommended maximum time a sensor should be stored in its original packaging before being installed in an instrument.

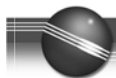
Storage Temp: The recommended temperature to store sensors prior to use.

Operating Life: The expected useable life of the sensor after it is installed, as long as the "Storage Life" was not exceeded before installation.

Warranty: The time from shipment up to which RAE Systems will replace a sensor free of charge, or at reduced charge, in case of failure. The warranty period is generally equal to or less than the Operating Life. Thus, a sensor with a storage life of 6 months, operating life of 2 years and warranty of 2 years, stored for one-half year before installation, is expected to be useable for up to 2½ years from the date of shipment, even though the warranty expires 1½ years after it is installed.

The expiration date of the warranty period is programmed into the sensor and is displayed during start-up of most RAE single gas and multi-gas meters. Sensors can be used beyond the expiration date provided that the sensor is properly zeroed and calibrated and the resolution is acceptable for the purpose of the measurements. The resolution can be tested by simply observing the zero fluctuations, or more accurately by measuring the response in the instrument's Diagnostic Mode according to Technical Note TN-123. The expiration date is provided on the instrument only as a reminder to the user that the warranty period for that sensor is complete and that it may become necessary to replace the sensor in the near future.

However, the sensor can operate properly beyond the expiration date as long as it responds to the gas of interest and is tested as noted above.

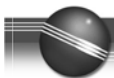


Calibration Gas: Recommended calibration gas concentration. A lower concentration might not give a stable calibration, while higher concentrations might use up the sensor prematurely. However, if the sensor is operated outside the typical range, it is recommended to use a calibration gas as close as possible to the actual concentrations and gas type being measured. For example, an NO sensor used to measure in the 200 to 500 ppm range is preferably calibrated with 500 ppm NO, instead of 25 ppm. A CO sensor used to measure 100 to

1000 ppm hydrogen should be calibrated with 1000 ppm hydrogen gas.

Calibration Flow Rate: Recommended calibration gas flow rate.

Cross-Sensitivity: Every sensor has some cross-sensitivity. It responds to other gases that are not filtered out and can react on the electrode. It is very important to be aware of potentially cross-sensitive compounds when interpreting data.



Calculating STEL, TWA, Min, Max, And Average Values For ToxiRAE PIDs

Introduction

This document gives an overview of the general meaning of TWAs and STELs and gives details on how these and other concentration data are determined and datalogged by the ToxiRAE PID, model PGM-30, through version 1.22 software. Depending on the datalogging options chosen, there may be differences between the instantaneously displayed values and the final datalogged values, as described below. The calculation methods also apply to nearly all other RAE instruments that datalog these values. All averages are calculated as arithmetic averages, rather than geometric.

Definition of TWA, STEL and Ceiling

Figure 1 gives a conceptual view of TWA, STEL and Ceiling values. Typically the TWA is the lowest value, STEL is somewhat higher and the Ceiling is the highest. Ceiling is the concentration that should never be exceeded, even for one instant. STEL is the Short Term Exposure Limit, which is a running 15-minute average concentration. The instantaneous concentrations may exceed the STEL value as long as they never exceed the Ceiling, and the 15-minute running average never exceeds the STEL limit. If the STEL alarm is reached, the worker must be removed from STEL level exposure for at least one hour. Workers can be exposed to a maximum of four STEL periods per 8 hour shift, with at least one hour between exposure periods.

TWA is a dose that should not be exceeded over either an 8-hour period (OSHA PELs and ACGIH TLVs) or a 10-hour period (NIOSH RELs).

Exposure Limit Illustration (TWA Higher than Peak)

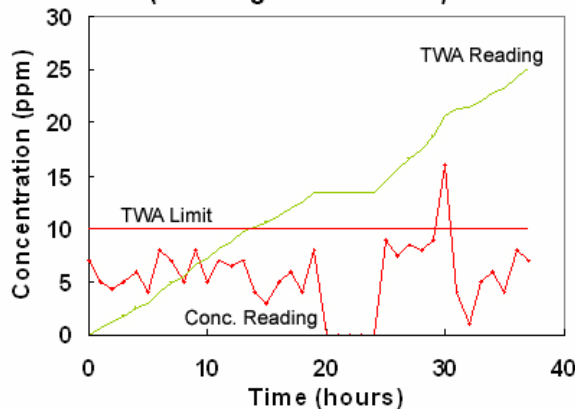
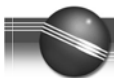


Figure 2. TWA can exceed the Peak value if readings are accumulated for more than 8 hours.

Displayed Values

- **Second Values:** Every second, the signal is sampled for several milliseconds and the data is averaged to give the instantaneous reading.
- **Minute Average:** The Second Values are added to a running sum and every minute this sum is divided by 60 to obtain a minute average. The Minute Average is not displayed, but is used to calculate the TWA and STEL. The Second Value, after the next instantaneous reading is made.
- **STEL:** The Minute Average values are then stored in a rolling buffer for fifteen minutes to calculate the STELs and then overwritten. The STEL is updated every minute as an average of the most recent fifteen Average Minutes.
- **TWA:** The Minute Average values are also used to update the TWA every minute, by adding to a running sum and dividing by the number of minutes in an eight-hour day (480). The TWA is the value accumulated from the time the instrument is turned on till the time of the last Minute Average, it assumes no further exposure from then on. The TWA continues to accumulate after eight hours until the instrument is turned off.



- **Peak Value:** The Peak Value is updated every second and is the highest measured Second Value since the unit was turned on.

Logged Values

The ProRAE-30 Program downloads minimum, average and/or maximum values within a defined datalogging period. The datalogging period is defined as a time interval within the total datalogging event. The user defines the datalogging period in one-second increments from one second up to one hour.

STEL and TWA values are not downloaded directly, but are recalculated from the downloaded minimums, averages or maximums.

- The **Minimum Value** is the lowest Second Value measured during each datalogging period.
- The **Average Value** is the arithmetic average of all Second Values measured during each datalogging period.
- The **Maximum Value** is the highest Second Value measured during each datalogging period.
- The **STEL** is calculated as the average of the maximum logged results of the previous fifteen-minute window:

$$\frac{\Sigma (\text{All max logged values in last 15 min})}{\# \text{ values in 15 min} = (15 * 60) / \text{period (sec)}}$$

- The **TWA** is calculated as:

$$\text{Previous TWA} + \frac{\text{max logged value} * \text{period (sec)}}{480 * 60}$$

Unlike a Running Average, the TWA is an accumulated exposure dose, and thus the value can never decrease

As noted before, the logged values can be different from the displayed values if inappropriate datalogging parameters are chosen. The program always uses the highest values available to calculate the TWA and STEL. To ensure that the displayed and logged values are identical, the user should chose a datalogging period of fifteen minutes or less. It is also suggested that the user log average only or average and minimum values, but not peak values.

Examples

Following are two examples. One shows you how to properly set up your instrument obtain correct Time Weighted Averages (TWA) and Short Term Exposure Limits (STELs). The other is an example of an improper set-up that will lead to false and missing data. We hope that you will find both of them interesting and informational.



Example ONE: Proper Set-up to Obtain correct TWA and STEL Values

11/05	10:52	-	10.7	-	0.7	0.0
	10:53	-	9.7	-	1.4	0.0
	10:54	-	8.7	-	1.9	0.1
	10:55	-	8.0	-	2.5	0.1
	10:56	-	7.4	-	3.0	0.1
	10:57	-	7.0	-	3.4	0.1
	10:58	-	6.7	-	3.9	0.1
	10:59	-	6.4	-	4.3	0.1
	11:00	-	6.2	-	4.7	0.1
	11:01	-	6.0	-	5.1	0.2
	11:02	-	5.8	-	5.5	0.2
	11:03	-	5.7	-	5.9	0.2
	11:04	-	5.5	-	6.3	0.2
	11:05	-	5.4	-	6.6	0.2
	11:06	-	5.3	-	7.0	0.2
	11:07	-	5.2	-	6.6	0.2
	11:08	-	5.1	-	6.3	0.2
	11:09	-	5.0	-	6.0	0.2
	11:10	-	4.9	-	5.8	0.3
	11:11	-	4.8	-	5.7	0.3
	11:12	-	4.7	-	5.5	0.3

1. Logged Avg Values only; TWA & STEL agree with the readout.
2. The first Fourteen minutes of STEL values always increase because they assume zero concentration before the first time point.
3. After Fifteen minutes STEL is correct because $\text{Period} < 7.5$ minutes and divides evenly into Fifteen.

Example TWO: Improper Set-up to Obtain Correct TWA & STEL

5/10	11:24	-	2.7	3.6	3.6	0.1
	11:34	-	1.7	2.7	2.7	0.2
	11:44	-	1.6	2.7	2.7	0.2
	11:54	-	2.2	4.4	4.4	0.3
	12:04	-	3.9	4.6	4.6	0.4
	12:14	-	4.1	5.4	5.4	0.5
	12:24	-	2.9	3.8	3.8	0.6
	12:34	-	1.4	1.9	1.9	0.6
	12:44	-	2.2	4.0	4.0	0.7
	12:54	-	3.0	3.9	3.9	0.8
	13:04	-	1.8	3.8	3.8	0.9

1. Logged Avg & Max values; TWA & STEL differ from the readout because they are calculated from Max values.
2. Period > 7.5 minutes; STEL does not average the last Fifteen minutes correctly; it only tracks the Max value.





Measuring PID Correction Factors For Volatile Compounds With Rae Systems Instruments

This Technical Notes details how to measure Correction Factors (CFs) for new compounds measured by MiniRAE 2000, ppbRAE Plus, ToxiRAE II and other RAE Systems photoionization detectors (PIDs). Correction Factors are used to allow measurement of a large variety of compounds while calibrating with only a single standard gas, commonly isobutylene.

In general, CFs are independent of the type of instrument and lamp size, as long as the lamp energy is the same. Therefore, any RAE Systems PID can be used to measure CFs, but it is often easiest to use a MiniRAE or ppbRAE because of their strong sampling pumps and fast response.

The matrix of the gas has important effects on the PID response. CFs listed in Technical Note TN-106 are measured in dry air and apply only to this condition. High humidity generally decreases the response by 30 to 50%. Measurements in pure nitrogen are the same as in air for a 10.6 eV or 9.8 eV lamp, but may give roughly a 10 to 30% increase in signal over dry air when using an 11.7 eV lamp. A correction factor measured with room air may be more representative of the actual use conditions, but is a less convenient reference point.

Correction Factor Definition

The correction factor is defined as the response of the isobutylene (IBE) calibrated PID to an equal concentration (ppmv) of the compound of interest (Gas Y):

$$CF = \frac{\text{Instrument's IBE Reading} * \text{Gas Y Concentration (ppmv)}}{\text{IBE Concentration (ppmv)} * \text{Gas Y Instrument Response}}$$

Thus, the higher the correction factor, the lower the sensitivity to the compound of interest. To account for any drift during the measurements, one can make isobutylene measurements before and after the sample measurements and take the average response to the isobutylene standard. It is preferable to use a gas standard of at least 50 to 100 ppmv for a MiniRAE or at least 5 to 10 ppmv for a ppbRAE in order to be well above the noise level of the instruments.

CF Measurement Using Gas Standards

If a cylinder of standard gas in dry air is available, simply calibrate the instrument with isobutylene measure the gas standard in the same way, and calculate the CF as above.

CF Measurement For Liquid Samples

If the gas standard is to be prepared from a liquid sample, proceed as follows:

- Obtain a large vessel such as a 5-gallon glass water jug or a 3-liter Tedlar gas bag.
 - If using a glass bottle, calibrate its volume. One simple way to do this is to fill the bottle with water and measure the difference in weight with an accurate balance (each kg of water equals 1 liter of volume).
Place some small inert objects (e.g., PTFE pieces) inside or use a magnetic stirrer to aid in mixing. Bore two holes in the cap to insert the instrument influent and effluent sample lines. Use PTFE tubing for these lines to minimize losses due to adsorption. For a ToxiRAE II, provide a large opening for the instrument sensor head, and seal this with a gasket or PTFE tape. Flush the sample vessel with clean, dry air.
- If using a Tedlar bag, fill the bag with a known volume of clean, dry air using a large-volume (e.g. 1.5-L) syringe.
- Calibrate the PID instrument with standard isobutylene gas.
- Using a microliter syringe, inject a volume of liquid calculated to give the desired concentration:

$$\text{Concentration (ppmv)} =$$

$$\frac{24.4 \text{ (L/mol)} * \text{Volume injected (}\mu\text{L)} * \text{Liquid density (g/mL)} * 10^6}{1000 \text{ (mg/g)} * \text{Molecular weight (g/mol)} * \text{Vessel volume (L)}}$$

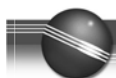
The amount injected typically ranges from 0.2 to 1.0 μL per liter of air. Allow time for the liquid to evaporate and mix. Assist mixing with magnetic stirring or agitation of the inert objects inside the closed vessel. Tedlar bags can be massaged to move the air inside. If the compound is high boiling, it may help to



apply heat (e.g., using a heat gun) to the vessel wall to speed evaporation. However, never heat a Tedlar bag, because this often releases compounds into the air giving a background PID response.

- Uncap the vessel and quickly insert the MiniRAE 2000 influent and effluent lines or the ToxiRAE II head. Recap or reseal as quickly as possible.
- Allow a minute or more for equilibration, record the sample measurement, and remove the instrument. Calculate the CF using the equation above.
- Repeat the process a few more times to obtain a calibration curve and several CF values to average.

If desired, a known volume of liquid water can also be injected to achieve a desired relative humidity and CF under humid conditions. For such measurements, the sensor must be very clean, or else the readings may drift upward.



CO Sensor Cross-Sensitivity And Removal With A Charcoal Filter

The table below shows data on the cross-sensitivity of the CO sensor* used in RAE Systems single-gas and multi-gas meters, both with and without carbon-impregnated filter pads (p/n 008-3006-005 for pack of 5) in front of the CO sensor. These filters can be used to reduce organic vapor cross-sensitivity. The filters should be stored sealed

and replaced frequently, especially after exposure to high organic concentrations. The CO sensor responds significantly to hydrogen, ethylene and isobutylene, and TCE, and hardly at all to ammonia, hydrogen sulfide, propane, hexane, and others.

Gas & Concentration	PID (10.6 eV)	New CO Sensor	New CO/filter	Used CO Sensor
100 ppm isobutene	100	9	4	≤100
500 ppm isobutene	548	30	20	≤170
1000 ppm isobutene	1060	28 ^a	22	≤260
2000 ppm isobutene	2030	80 ^a	70	≤680
100 ppm propane	0	0	0	0
100 ppm butane	0	1	1	
100 ppm hexane	25	0	0	0
250 ppm acetylene	250	250		
200 ppm ethanol	20	0	0	0
125 ppm ethylene oxide	~10	≥40		
100 ppm ammonia	7	0	0	0
10 ppm H ₂ S	~2	0	0	≤9
15 ppm H ₂ S	~4	1	0	≤13
100 ppm MEK	99.5	0	0	0
100 ppm TCE	189	25	15	0
5 ppm SO ₂	0	0	0	≤3
35 ppm NO	~6	1	1	≤5
5 ppm NO ₂	≤0.5	0	0	≤2
1000 ppm (0.1%) H ₂	0	420	360	≤600
100 ppm H ₂	0	40	31	≤50
100 ppm ethylene	10	24	20	≤100

* Data were taken using RAE Systems CO sensors.

^a Values after 2 minutes; after 5 minutes the apparent CO readings increase about 25% more.

New vs. Used CO Sensors

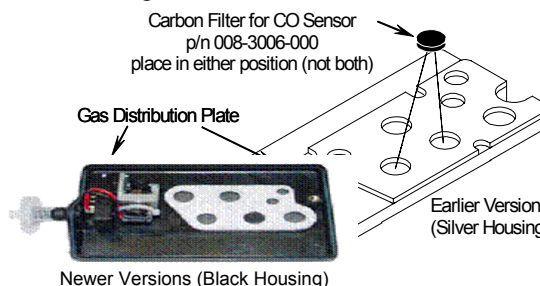
The RAE Systems CO sensor has a built-in oxidizing chemical filter that is designed to remove ppm level H₂S for 2 years. The table above shows that a new sensor also shows no or low response to isobutylene. However, the built-in filter can be burned out by high doses of H₂S or organic vapors. After that time, the cross-sensitivity to VOCs increases. When using 100 ppm isobutylene to calibrate a Multi-gas meter having both PID and CO sensors, a response of 30 to 65 ppm is commonly observed on a used CO sensor. A good charcoal (carbon) filter should eliminate most of that cross-sensitivity.

Maintenance of Carbon Filter for CO Sensors

The carbon filter is 0.35" in diameter. When a CO sensor is installed in the MultiRAE monitor, the carbon filter should be inserted into the corresponding opening on the gas distribution plate for the CO sensor (see figure). This carbon filter lasts for about 4 to 6 weeks under normal operation conditions before needing replacement. However, if the monitor is exposed to high VOC concentrations, the carbon filter should be replaced more frequently. To check the carbon filter, apply a known

VOC gas, such as 100 ppm isobutylene, to the monitor. If the CO sensor exhibits readings above 5 ppm, it is time to replace the carbon filter. To replace the filter, simply open the gas distribution plate, use a tweezers to remove the old filter, and insert a new one into the opening. On an old, used sensor, some response with isobutylene is expected even with the carbon filter in place.

Warning: The carbon filter used for CO sensors may lower the reading if used on other sensors such as H₂S, NH₃, or Cl₂. Remove the filter if another sensor replaces a CO sensor in the multi-gas meter.





PID Lamp Characteristics

PID Lamp Selection

RAE Systems photoionization detectors (PIDs) currently offer lamps with three different photon energies: 9.8 eV, 10.6 eV and 11.7 eV. A special high-intensity version of the 10.6 eV lamp is also available for use with ppbRAE Plus. Instruments are shipped with the standard 10.6 eV lamp unless otherwise specified. The 11.7 eV lamp measures the broadest range of compounds, while the 10.6 eV lamp is somewhat more selective, and the 9.8 eV lamp is the most selective. Because of the different type of lamp window needed to allow the higher energy light to pass, the 11.7 eV lamp has a shorter life (see table) and is more expensive. Therefore we recommend using the 9.8 or 10.6 eV lamps whenever possible.

Lamp Output and Resolution

The larger (1/2") lamps used in the MiniRAE 2000, ppbRAE Plus, UltraRAE and RAEGuard have greater output than the smaller (1/4") lamps used in the ToxiRAE, MultiRAE and AreaRAE. 10.6 eV lamps also have stronger output than 11.7 eV lamps. The IAQRAE and AreaRAE IAQ use a 3/8" 10.6 eV lamp/sensor combination with intermediate output. Higher output translates to better resolution and lower detection limits. The resolution also depends on the type of compound measured; generic values for isobutylene are listed below. The "super-bright" 10.6 eV lamps are required for ppb level detection, and the ppbRAE Plus cannot use 11.7 eV lamps. These stronger lamps are not recommended for other PIDs because they may saturate the sensor at high VOC concentrations.

Lamps Stored in Glass Ampules

Because lamps gradually lose power even when not in use, the warranty periods listed below apply even if the lamp is not turned on. New 1/4" 11.7 eV lamps shipped in sealed ampules are warranted for storage of 3 months. The 1-month operating warranty begins at the earlier of the 3-month storage period or when the gas-tight container is opened. In order to maintain the warranty, these dates must be recorded.

Lamp Care

Store lamps under dry conditions to minimize attack on the lamp window. Keep the lamps clean using dry methanol; never use acetone on 11.7 eV lamps. Turn off 11.7 eV lamps when not in use, to minimize yellowing of the window. Storing an entire ToxiRAE II unit in a dessicator between uses extends the life of the 11.7 eV lamp without the need to remove the lamp repeatedly.

Lamp Driver

In MiniRAE 2000s the lamp driver (LDRV) may be increased in the Diagnostic Mode to help turn on 11.7 eV lamps or extend their useable life. 10.6 eV lamps are normally operated at LDRV of 175. 11.7 eV lamps use LDRV of 200 but can be increased to 225 if they fail to turn on after some use. The ppbRAE uses LDRV of 200 for 10.6 eV lamps as a default. If LDRV is changed, the lamp fail threshold may need to be adjusted also. Use of a higher LDRV than necessary slightly decreases battery life and response linearity. Firmware versions 1.22 for the MiniRAE 2000 and ppbRAE introduced automatic lamp drive adjustment, and the LDRV and Fail menus are absent from the Diagnostic Mode menu. In Version 1.23 these reappear and allow the user to set the LDRV. However, the monitor still measures the optimal LDRV and may override the user's set point if it is too low to turn on the lamp.

Lamp Replacement

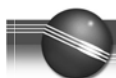
RAE Systems PID lamps do not burn out suddenly, because they have no filament. Thus, because of the shorter life, we recommend purchasing 11.7 eV lamps as close as possible to the date of use. The strength of the lamp, and thus its expected life, can be determined using the special Diagnostic Mode (See Technical Note TN-123).



Lamp Warranties and Resolution

Lamp Energy	Part Number	Lamp Diameter	Typical Resolution	Warranty Period	Typical Life
9.8 eV	050-0020-000	1/2"	0.1 ppm	6 months	1 year
9.8 eV	050-0030-000	1/4"	0.2 ppm	6 months	1 year
10.6 eV*	050-0000-000	1/2"	0.1 ppm	1 year (3 yrs)*	2 to 3 years
10.6 eV super bright	050-0000-001	1/2"	0.002 ppm	1 year	1 year
10.6 eV	050-0010-000	1/4"	0.1-0.2 ppm	1 year	1 year
10.6 eV	023-0601-106	3/8"	0.02 ppm	1 year	1 year
11.7 eV	050-0001-000	1/2"	0.1-0.2 ppm	1 month	1 to 2 months
11.7 eV in ampule	050-0011-001	1/4"	1.0 ppm	1 month	1 to 2 months

* 10.6 eV lamps used in MiniRAE 2000 are warranted for 3 years, as long as the warranty card is returned.



Benzene-Specific Measurements In Petroleum Hydrocarbons Using The RAE Systems UltraRAE 3000

Introduction

Benzene is a known human carcinogen that is present in automotive gasoline and other fuels in concentrations typically 0.2 to 3%. Its regulated exposure limit is so low (proposed 8-hour day TWA of 0.5 ppm), that its concentration alone usually defines the toxicity of the fuel vapors as a whole. Thus, it is necessary to measure low concentrations of benzene (often ≤ 1 ppmv) in the presence of much higher concentrations (tens to hundreds of ppmv total) of the hundreds of aromatic and aliphatic compounds that make up gasoline.

Specific Benzene Measurements

RAE-Sep™ benzene tubes scrub nearly all components out of gasoline vapors except benzene. This is accomplished through a proprietary absorption medium in the tubes. Further selectivity is afforded by using a 9.8 eV lamp, which responds strongly to aromatics but weakly to many hydrocarbons. Table 1 shows the response of the combined system to various challenge gases.

Measurement Procedure

A separate tube is used for each measurement. The instrument is calibrated using a 5 ppm benzene standard with a RAE-Sep™ tube in place. When ready to measure, a tube is opened, it is inserted into the UltraRAE 3000, and the start button is pushed. A pump draws in the air sample at about 330 cc/min. and the unit automatically fixes the display and logs the value after 30 to 280 seconds, depending on the temperature.

Tube Capacity and Matrix Effects

Benzene RAE-Sep™ tubes withstand 1000 ppm of toluene in dry air and 300 ppm at 50 to 80% RH (relative humidity). Tubes can be opened and left exposed to air for up to 4 hours without losing significant capacity.

Table 2 shows that humidity has no effect on the response to benzene. However, high humidity affects the capacity of the tube to remove interfering hydrocarbons.

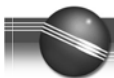
Table 1. Response to potential benzene interferences.

Compound	Concentration (ppmv)	Apparent Benzene Response
Toluene	400	0.1
p-Xylene	200	0.0
Ethylbenzene	200	0.0
Styrene	100	0.0
Nitrobenzene	100	0.0
Phenol	100 [#]	0.0
Chlorobenzene	20	2.5
Dichlorobenzene	50	0.1
Hydrogen Sulfide	150	0.0
Methane	25,000**	0.0
Propane	1,000	0.0
Isobutane	100	0.0
Isobutylene	500	0.0
n-Pentane	1,500	0.0
1,3-Butadiene	300	0.0
n-Hexane	100 [#]	0.0
Cyclohexane	10	0.4
n-Octane	300	0.1
β-Pinene	50	0.0
Ethanol	50	0.0
Isopropanol	100	0.0
Acetone	100	0.0
Cyclohexanone	200	0.0
Tetrahydrofuran	100	0.0
Ethyl acetate	100	0.0
Acrylonitrile	100	0.0
Epichlorohydrin	100	0.0
Trichloroethylene	100	66
Perchloroethylene	50	38

*Not necessarily the maximum allowable concentration.

** No effect on tube capacity. Propane and higher hydrocarbons do affect capacity.

[#] Higher concentrations may cause a reduced benzene response.



Methane has no effect on tube capacity, but it reduces the response of the PID to benzene, when the methane concentration is above about 1% by volume. Propane and higher hydrocarbons consume part of the capacity of the tubes even if they give no response.

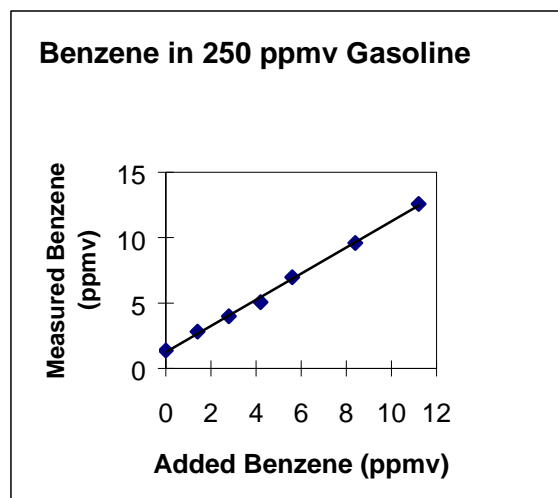
Table 2. Humidity effect on 5 ppm benzene standards.

Tube #	Relative Humidity	Reading (ppm)
1	Dry	5.0
2	Dry	4.9
3	100 %	5.1
4	100 %	4.8

Sample Measurements

Figure 1 shows the linearity of the response when benzene is added to a sample of gasoline vapors. The correlation coefficient (r^2) for the line is 0.998. This excellent linearity allows the use of a fast and simple single-point calibration.

Figure 1. Linearity of benzene response added to 250 ppmv of 92 octane gasoline. The sample contains 1.4 ppmv of benzene from the gasoline itself.



Refinery Samples

Petroleum refineries have a variety of process streams that contain a broad range of benzene concentrations. Table 3 compares the results of the benzene-specific UltraRAE, obtained in one minute, with those of two-hour gas

chromatography (GC) runs in the laboratory. The good correlation between the two measurement systems shows the benefit of the time savings afforded by the UltraRAE 3000.

Table 3. Benzene in refinery samples.

Sample	Benzene by GC/FID (mole %)	Benzene by UltraRAE (mole %)
87 Octane Gasoline	0.86	0.63
Reformer Feed	1.2	1.0
Reformer Product	6.3	7.2
Benzene Light Ends	22	24

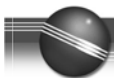
Field Comparison

A study was conducted at four major oil refineries comparing the UltraRAE 3000 with three other benzene-specific portable measurement systems: the Photovac Snapshot handheld GC, the Dräger CMS, and laboratory GC. The results shown in Table 4 were obtained for the combined data from 18 different field samples and 24 standards, including BTEX mixtures:

Table 4. Field sample accuracies as percent of laboratory value \pm standard deviation.

Sample	UltraRAE	Snapshot	CMS
Standards	101 \pm 16%	116 \pm 23%	120 \pm 52%
Field Samples	97 \pm 29%	84 \pm 21%	103 \pm 92%

The Snapshot and UltraRAE 3000 gave similar results while the CMS tended to have greater variability. Complete results of the study are available on request.



UltraRAE And UltraRAE 3000 Operation Tips

This document describes several helpful tips for operating the UltraRAE and UltraRAE 3000.

Sampling With The UltraRAE

How To Make An Airtight Seal For The Inlet Probe

When inserting a RAE-Sep tube into the inlet adapter, push the tube into the rubber gasket until you feel that the tube is properly sealed. Next screw on the tube holder cap to seal the other end of the RAE-Sep tube. Then simultaneously twist and push down on the tube cap nut to ensure that the rubber adapters inside the tube holder form good seals against both ends of the RAE-Sep tube.



How To Select The Tube Name

1. Remove the tube from the inlet. Press [Y/+] while the UltraRAE displays the “Ready...” message.
2. The display should show “No Tube” and “Manual select?” press [Y/+].
3. The display should show a tube name, such as “Benzene?” Press [N/-] if you want to change the tube name. Press [Y/+] to accept the tube name.
4. The display should show the selected tube name and “Start?” message alternately. Press [Y/+] to start the testing.

What To Do If The Tube Reader Shows “Invalid Lamp ForXxxx Tube”

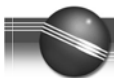
This message means that the UV lamp installed inside the unit does not work with the given tube. The correct UV lamp information (9.8 eV, 10.6 eV or 11.7 eV) is printed on the label of the tube box. After installing the correct lamp, the user also needs to change the monitor setup because the unit will not

recognize the lamp type automatically:

1. Press both the [N/-] and [MODE] keys together for 3 seconds, the display shows the first programming mode menu: “Calibrate Monitor?” Press [N/-] four times.
2. The display should show “Change Monitor?” Press the [Y/+] key.
3. The display should show “Change Measure Wait Time?” Press the [N/-] key.
4. The display should show “Change lamp?” Press the [Y/+] key.
5. The display should show “Lamp = xxxx eV?” where “xxxx” is the current UV lamp selection.
6. Press the [N/-] key until the correct UV lamp type is displayed. Then press [Y/+] key to accept the correct UV lamp. Press the [Y/+] key again to confirm the change.
7. Press the [MODE] key twice to return to normal display with “Ready...” message. The unit is now ready to accept the tube with the newly installed UV lamp.

Note About Multiple-Tube Operation

When using different types of RAE-Sep tubes in the UltraRAE, it is very important to calibrate each type of tube before using the monitor. Thereafter, simply insert the tube into the inlet adapter, and the tube reader will recognize the tube name and use the proper calibration data to perform the gas measurement. If there are more than eight different types of tubes available, the PC program (ProRAE Suite) must be used to select eight tubes and download the tube data to the monitor. See the Operation and Maintenance Manual for details on the download procedure.



Sampling With The UltraRAE 3000

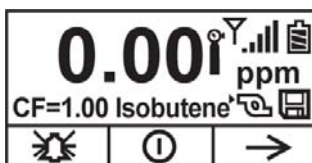
Before performing a compound-specific measurement for Benzene or Butadiene using a RAE-Sep separation tube, make sure the UltraRAE 3000 is in Tube Mode and that the appropriate tube type is selected. The UltraRAE 3000 only acts as a compound-specific measurement device when it is equipped with a 9.8eV lamp. Therefore, make sure the UltraRAE 3000 is equipped with a 9.8eV lamp and manually set to use it whenever it is to be used for compound-specific sampling such as for benzene.



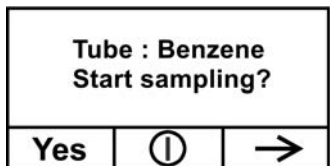
Make sure the UltraRAE 3000 is set to operate with your selected tube:

1. Enter Programming Mode.
2. Select Measurement.
3. Select Tube Selection.
4. Make a choice of Benzene or Butadiene.
5. Save your choice.

To begin measuring, turn on the UltraRAE 3000. This screen is shown, which includes the CF (correction factor) and measurement gas type (benzene, butadiene, etc.) for calibration reference:



Press [N/-] to advance. You will see this screen:



Do not begin sampling yet!

Before you start sampling, you must insert a RAE-Sep separation tube into the inlet/holder. Follow the Separation Tube Preparation and Placing A Tube Into

The UltraRAE 3000 instructions before pressing any buttons on the UltraRAE 3000. Once the tube is in place, then proceed to measuring.

IMPORTANT!

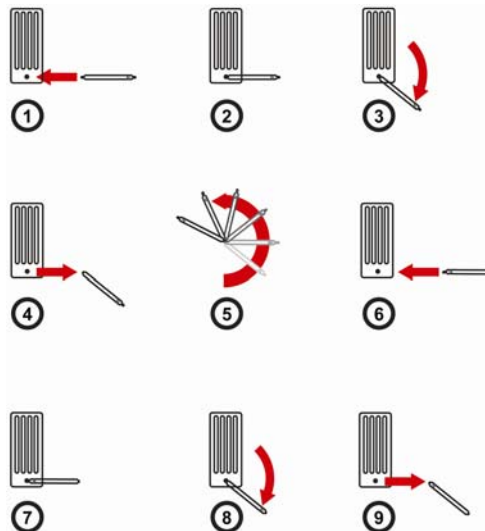
Once a tube's ends are broken off, the material inside is exposed. Therefore, use the tube for sampling as soon as possible.

Separation Tube Preparation

CAUTION!

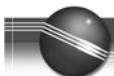
Wear hand and eye protection when breaking tube tips. Use caution in handling tubes with broken ends. Keep away from children. RAE-Sep tubes should be disposed of according to local regulations. See footnotes of data sheets for disposal information.

1. Open a package of RAE-Sep separation tubes and remove one.
2. Place the tip in the package's tube tip breaker (the small hole on the front) and snap off the tip.
3. Turn the tube around and snap off the other end.



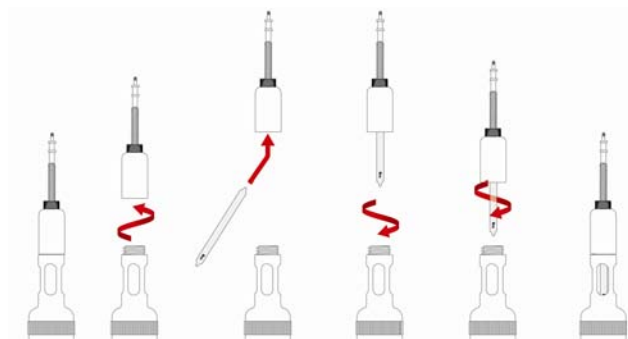
CAUTION!

Handle tubes with care. Tube ends are sharp after ends are broken off.



Inserting The Separation Tube

1. Unscrew the front of the sampling probe from the base.
2. Slip the tube into the rubber holder in the front portion.
3. Insert the other end of the tube into the middle of the base while turning the front portion to tighten it onto the base's threads.



IMPORTANT!

Do not overtighten any portion of the sampling assembly.

Measuring

WARNING!

If a 15-minute test is performed and less than 1/4 of the tube is not yellow-orange at the bottom, retest with a new tube for 1 minute. If at least 1/4 of the tube is not yellow-orange at the bottom, the test should not be considered valid, and VOCs may be dangerously high.

Once the tube is in place, begin measuring by pressing [Y/+].

The display shows a countdown (60 seconds is shown here, but sampling time depends on the type of separation tube selected and the temperature):

Wait ... 60		
		Abort

Note: You can abort the sampling by pressing [N/-] at any time.

Once the countdown is complete, the reading is shown:

Benzene= 0.00 ppm Continue and establish STEL?		
Yes		No

Press [Y/+] to continue sampling with the tube for 15 minutes to establish a STEL reading, or press [N/-] to return to the main menu.

WARNING!

At least 1/4 of the tube should still be yellow-orange at the bottom. If not, the STEL value is not valid. Abort the measurement and change the tube. Then do a snapshot test instead of a STEL test. **Note:** If the STEL is exceeded, the UltraRAE 3000 goes into alarm.

If you press [N/-] to return to the main menu, which shows the tube type instead of the CF (correction factor):

0.00i ppm		
Tube = Benzene		
Y/+	N/-	→

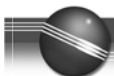
Press [N/-] to advance to this screen:

TWA: - - - - ppm		
STEL: - - - - ppm		
Peak: 0.00 ppm		
Clear	Y/+	→

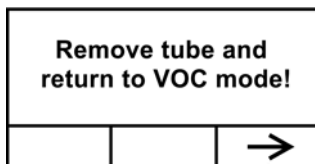
If you press [Y/+], you are asked, "Clear peak value! Are You Sure?" to confirm:

Clear peak value! Are you sure?		
Yes		No

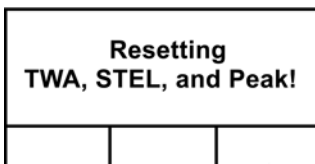
Press [Y/+] to clear the Peak value and exit to VOC operation.



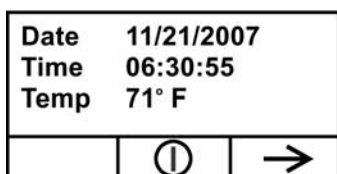
If you press [N/-], this display is shown:



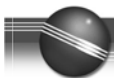
Remove the tube and put the inlet back together.
Then press [N/-]. This display is shown:



After a few seconds, the UltraRAE 3000 enters VOC mode and shows this display:



You can step through the rest of the steps by pressing [N/-] repeatedly until you reach the main menu again.



Electrochemical Sensor Replacement & Maintenance

This technical note describes sensor replacement and maintenance procedures for electrochemical and combustible gas (LEL/TC) sensors used in RAE Systems instruments, including MultiRAE, QRAE, and VRAE. For technical specifications of sensors, see Technical Note TN-114, and for handling LEL sensor poisons, Technical Note TN-144. For CO sensor cross-sensitivity and filters, see Technical Note TN-121.

General

- Prepare a clean workspace and wash hands well before installing sensors. Greases and oils can cause sensors to perform poorly. LEL sensors are particularly sensitive to damage from silicone lubricants, including hand lotions.
- Turn off the power to the unit and remove the instrument cover.
- Disconnect the battery before replacing a sensor.

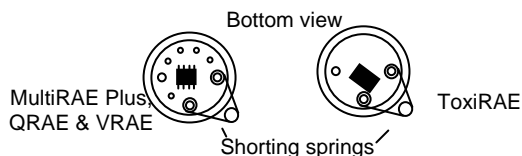


Warning: Failure to turn off the power during replacement can cause damage to some sensors. Failure to disconnect the battery can cause the non-replaceable fuse in the battery to blow.

Sensor Replacement Procedures

Remove the gas distribution plate, if any. Carefully pull the existing sensor straight out.

- Some electrochemical sensors are shipped with a shorting spring connecting two of the large pins to keep the sensor stabilized during storage. Remove any shorting spring before installing the new sensor.



Replace the spring if the sensor is removed from the instrument for more than several minutes. Lack of a shorting wire will not damage the sensor, but if it is missing for more than about 10 minutes, the sensor may require an hour or more to fully equilibrate after being installed. Biased and LEL sensors do not have shorting springs.

- Insert the sensor by carefully lining up the sensor pins with the sockets in the circuit board. To avoid damaging the internal contacts, use caution and do not bend the pins on the sensor. Bent sensor pins can be carefully bent back using long-nose pliers.
- Do not push the sensors down too hard while installing, as this may cause damage to the circuit board components underneath the sensor.
- After reassembly, the unit may go into alarm if turned on immediately. Allow about 10 minutes for the sensor to stabilize in the unit before turning on the instrument. For maximum accuracy, non-biased toxic sensors should be allowed to stabilize for one hour before calibrating. Biased sensors require a 24-hour stabilization time with batteries installed.
- Re-zero and recalibrate new sensors prior to use.

Biased Sensors (NO)

Nitric Oxide (NO) sensors require a voltage bias and must be installed in position 1 of the MultiRAE Plus and positions 1 through 3 of the VRAE, and the bias switch must be turned *on*. See the figures at the end of this Technical Note for the positions of the bias switches and sensors.

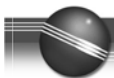


Warning: Failure to install NO sensors in the biased position can damage the sensors. Using shorting springs on bias-type sensors can damage the sensors.

Biased sensors require a 24-hour stabilization time with batteries installed. If you receive a new unit with this sensor, install the batteries and wait overnight before attempting to calibrate the sensor. Units with rechargeable batteries must be kept at minimal charge to main the bias on the sensor. If the sensors or batteries are disconnected for more than a few seconds, it may require several hours to again stabilize the sensor.

Recalibration

The MultiRAE remembers the last calibration on a given sensor position. If a sensor is traded out, the new sensor needs about one hour to equilibrate, and it must then be recalibrated. In the case of a sensor with an electrical bias (NO), it must equilibrate about 24



hours before calibrating. We recommend calibrating whenever a sensor is removed, even if the same sensor is reinstalled in the same location.

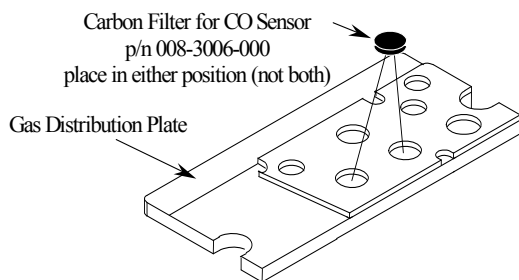
Filters

It is good practice to replace filters at the same time a sensor is replaced. Filters may need replacement more frequently if clogged or saturated. Filter replacement is indicated when the sensor begins to respond slowly or take a long time to recover from an exposure. In addition to the instrument inlet filters designed to remove particles and water droplets, some sensors (for example, CO) need other external filters for proper operation.

- **ToxiRAE membrane filter & MultiRAE/QRAE filter cartridges.** Replace when visibly dirty or when sensor response become slow.
- **CO sensor carbon filter.** Replace when response to organic vapors is noted or every six months, whichever comes first. This filter is located in the MultiRAE, VRAE or QRAE cover plate.
- Remove the carbon filter if another sensor is used to replace a CO sensor. For example, if an SO₂ or Cl₂ sensor is installed, the carbon filter removes these gases and low readings are obtained.



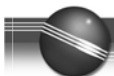
Warning: Failure to remove the carbon filter in the MultiRAE Plus cover plate for sensors other than CO may result in low readings.



Storage

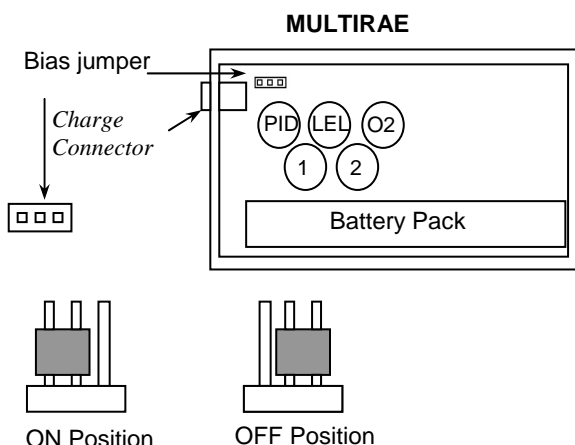
Sensors can dry out or burst if stored at very low or very high relative humidity, respectively. To maximize sensor life, store sensors and instruments indoors in a climate-controlled building. Note other special conditions:

- Cl₂ sensors are particularly sensitive to high relative humidity and may burst if stored in a refrigerator.
- Oxygen sensors are always on and are being consumed by ambient air. These sensors are shipped in oxygen-impermeable bags. The shelf life can be extended by keeping the sensor in the impermeable bag until it is used.
- Replace shorting springs on non-biased sensors for rapid start-up when reinstalled.
- Store LEL sensors away from possible catalyst poisons such as silicone-containing greases or rubbers, sulfur compounds, and chlorine compounds.
- The plastic containers used to ship sensors are not air-tight and do not provide long-term protection from humidity extremes, O₂, or LEL poisons.

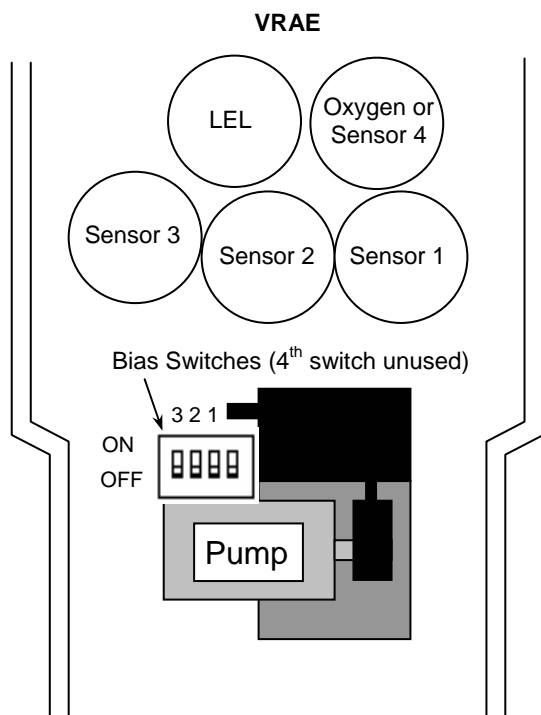


Bias Switch Locations

Nitric Oxide sensors should be placed in position 1 on the MultiRAE and positions 1 to 3 on the VRAE. The MultiRAE Plus uses a jumper moved from the right two pins to the left two pins to turn on the bias. The VRAE uses three switches pushed up towards the sensors to turn on the bias. The MultiRAE can have one biased sensor and the VRAE up to three.



MultiRAE top view with cover plate removed showing location of bias jumper and sensor positions.



VRAE Internal view showing location of bias switch position and sensor positions

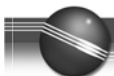
Interchangeability

Single Sensor in Different Instruments

- Sensors for the MultiRAE, QRAE, QRAE Plus, and VRAE are interchangeable among instruments, except for the LEL/VOL sensor. The MultiRAE and QRAE use the 4R sensor only (p/n 008-1171-002), the VRAE uses either the 4R (p/n 017-1171-000) or 4R/TC sensor (p/n 017-1172-000), and the QRAE Plus uses the 3R/TC sensor (p/n 016-1171-000 or 016-1172-000). The CO₂ sensor can only be used in the MultiRAE IR.

Different Sensors in a Single Instrument

- In the MultiRAE and VRAE, all sensors including the HCN and PH₃ sensors (p/n 008-1117 and 19) *are* interchangeable. Thus, any combination of sensors is possible, except that the MultiRAE can have only one biased sensor (NO) because there is only one bias position. In the VRAE, sensors with a negative current (NO₂, Cl₂, and ClO₂) cannot be placed in position 3, and in the VRAE, sensors with a bias or negative current cannot be placed in position 4 (see table below).
- The QRAE is limited to the four standard sensors LEL/O₂/CO/H₂S.



Sensors		PGM-7800		PGM-7840	
Gas	Bias	Tox1,2 Loc.	Tox3 Loc.	Tox1,2,3 Loc.	Tox4 Loc.
CO	Off	OK	OK	OK	OK
H ₂ S	Off	OK	OK	OK	OK
SO ₂	Off	OK	OK	OK	OK
NO	On	OK bias on	OK bias on	OK bias on	Not allowed
NO ₂	Off	OK	Not allowed	OK	Not allowed
Cl ₂	Off	OK	Not allowed	OK	Not allowed
ClO ₂	Off	OK	Not allowed	OK	Not allowed
NH ₃	Off	OK bias off	OK bias off	OK bias off	OK bias off
HCN	Off	OK	OK	OK	OK
PH ₃	Off	OK	OK	OK	OK

Extended Calibration Times

Slowly responding sensors listed in the table below may require pre-exposure of the sensor to the gas immediately before initiating the calibration sequence. Some firmware versions use a fixed 60-second calibration time; some newer versions automatically apply the full calibration time. After completing the

zero calibration, expose the unit to the gas for the pre-exposure time listed below if a 60-second countdown time is programmed in the unit. In many cases when a pre-exposure is performed, the unit gives a warning message “No gas...” when calibration is initiated. Simply push the [Y/-] button to bypass the warning and proceed with the calibration.

Sensor	Response Time t_{90} (sec)	Total Calibration Time (sec)	Pre-exposure Time for 1-min Calibration Time
HCN	200	230	170
ClO ₂ , NH ₃ , COCl ₂	150	150	90
Cl ₂ , PH ₃	60	120	60
CO, H ₂ S, SO ₂ , NO, NO ₂ , O ₂ , LEL, VOL	≤40	60	0



Effects Of Operating Conditions On Oxygen Sensors

Matrix Gas Effects Humidity. Humidity affects the oxygen sensor only by diluting the oxygen in the air. This effect is greater at higher temperatures, as seen in the table below.

Humidity Effect on Apparent Reading (%) in Air

RH	0° C	20° C	40° C
0%	20.9	20.9	20.9
50%	20.9	20.7	20.2
100%	20.8	20.5	19.4

Cross-sensitivity. Parts-per-million levels of other gases have no effect on oxygen sensors. Oxidizing gases like chlorine, bromine, chlorine dioxide, and ozone at percent levels interfere proportionally to their oxygen equivalence.

Cross-sensitivity to Matrix Gases

Gas	Concentration (Volume %)	% of Signal Change
CO	20%	<0.5%
CO ₂	20%	~6%
CH ₄	100%	0
H ₂	100%	<-2%
Hydrocarbons	100%	0

Oxygen sensors are be damaged when used continuously in >25% CO₂ or SO₂, which absorb into the electrolyte, causing an increased signal. SO₂ also reacts to reduce oxygen under very high humidity contitions.

Carrier Gas Effect. High concentrations of matrix gases other than nitrogen (e.g., air), affect the response of one-year capillary oxygen sensors. The effect depends on the molecular weight difference in the matrix gas:

$$\text{Reponse} = \text{Response in N}_2(\text{air}) \times \sqrt{28/\text{MW}}$$

Where MW = average molecular wt. of the matrix gas:

$$28 = \text{molecular wt. of nitrogen}$$

For example, for a sensor calibrated in air and used to measure in 80% helium/20% nitrogen mix:

$$\text{Average molecular wt.} = 0.8(4) + 0.2(28) = 8.8$$

$$\text{Reponse} = \text{Response in N}_2(\text{air}) \times \sqrt{28/8.8} = 1.78$$

Therefore, the reading is 78% higher in the He/N₂ mix and would need to be divided by 1.78 to obtain the true reading.

Pressure Effects

The normal operating range for oxygen sensors is within 20% of ambient pressure. Pressure changes are common in such places as entering a tunnel, going up in a high-rise building, or flying in an airplane. RAE Systems provides both one-year and two-year oxygen sensors, and pressure effects on the two-year sensors are generally more pronounced.

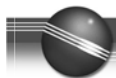
Capillary sensors used by RAE Systems offer the advantage over non-capillary sensors in that their final response is unaffected by ambient pressure. They measure true volume percent. However, when a sudden pressure change occurs, the sensor gives a transient high or low response (pressure increase causes a high reading and vice versa). This transient response decays quickly to a stable reading in less than one minute when using a 1-year sensor. On the other hand, 2-year sensors have a narrower orifice that results in a slower response to pressure changes. The 2-year sensors may take several minutes to stabilize after a pressure change. Therefore, it is likely that the unit will alarm after a sudden pressure change. In such cases, the unit should be allowed to equilibrate for several minutes under the new pressure before turning on or recalibrating. After pressure equilibration, the response time of the 2-year sensors returns to normal and provides adequate protection.



Warning: The 2-year oxygen sensor may cause an alarm when subject to a sudden pressure change even when a safe level of oxygen is present.

Temperature Effects

Oxygen sensors show almost no effect of gradual temperature changes, the response being <15% lower at -20° C (-4° F) than at +50° C (+122° F). Sudden temperature changes cause a transient response similar to those caused by pressure changes, but in the opposite direction (a reduced response with a temperature increase and a high response at lower temperature). A sudden temperature change may cause the instrument to alarm, but the reading should equilibrate in <30 seconds. Temperatures over 100° C (212° F) permanently damages the sensors.



Correction Factors, Ionization Energies*, And Calibration Characteristics

Correction Factors and Ionization Energies

RAE Systems PIDs can be used for the detection of a wide variety of gases that exhibit different responses. In general, any compound with ionization energy (IE) lower than that of the lamp photons can be measured.* The best way to calibrate a PID to different compounds is to use a standard of the gas of interest. However, correction factors have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically isobutylene. In our PIDs, correction factors can be used in one of three ways:

- 1) Calibrate the monitor with isobutylene in the usual fashion to read in isobutylene equivalents. Manually multiply the reading by the correction factor (CF) to obtain the concentration of the gas being measured.
- 2) Calibrate the unit with isobutylene in the usual fashion to read in isobutylene equivalents. Call up the correction factor from the instrument memory or download it from a personal computer and then call it up. The monitor will then read directly in units of the gas of interest.
- 3) Calibrate the unit with isobutylene, but input an equivalent, "corrected" span gas concentration when prompted for this value. The unit will then read directly in units of the gas of interest.

** The term "ionization energy" is more scientifically correct and replaces the old term "ionization potential." High-boiling ("heavy") compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like H₂O₂ and NO₂ give weak response even when their ionization energies are well below the lamp photon energy.*

Example 1:

With the unit calibrated to read isobutylene equivalents, the reading is 10 ppm with a 10.6 eV lamp. The gas being measured is butyl acetate, which has a correction factor of 2.6. Multiplying 10 by 2.6 gives an adjusted butyl acetate value of 26 ppm. Similarly, if the gas being measured were trichloroethylene (CF = 0.54), the adjusted value with a 10 ppm reading would be 5.4 ppm.

Example 2:

With the unit calibrated to read isobutylene equivalents, the reading is 100 ppm with a 10.6 eV lamp. The gas measured is m-xylene (CF = 0.43). After downloading this factor, the unit should read about 43 ppm when exposed to the same gas, and thus read directly in m-xylene values.

Example 3:

The desired gas to measure is ethylene dichloride (EDC). The CF is 0.6 with an 11.7 eV lamp. During calibration with 100 ppm isobutylene, insert 0.6 times 100, or 60 at the prompt for the calibration gas concentration. The unit then reads directly in EDC values.

Conversion to mg/m³

To convert from ppm to mg/m³, use the following formula:

$$\text{Conc. (mg/m}^3\text{)} = \frac{[\text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)}]}{\text{molar gas volume (L)}}$$

For air at 25 °C (77 °F), the molar gas volume is 24.4 L/mole and the formula reduces to:

$$\text{Conc. (mg/m}^3\text{)} = \text{Conc. (ppmv)} \times \text{mol. wt. (g/mole)} \times 0.041$$

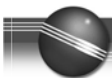
For example, if the instrument is calibrated with a gas standard in ppmv, such as 100 ppm isobutylene, and the user wants the display to read in mg/m³ of hexane, whose m.w. is 86 and CF is 4.3, the overall correction factor would be 4.3 x 86 x 0.041 equals 15.2.

Correction Factors for Mixtures

The correction factor for a mixture is calculated from the sum of the mole fractions X_i of each component divided by their respective correction factors CF_i:

$$\text{CF}_{\text{mix}} = 1 / (X_1/\text{CF}_1 + X_2/\text{CF}_2 + X_3/\text{CF}_3 + \dots X_i/\text{CF}_i)$$

Thus, for example, a vapor phase mixture of 5% benzene and 95% n-hexane would have a CF_{mix} of $\text{CF}_{\text{mix}} = 1 / (0.05/0.53 + 0.95/4.3) = 3.2$. A reading of 100 would then correspond to 320 ppm of the total mixture, comprised of 16 ppm benzene and 304 ppm hexane.



For a spreadsheet to compute the correction factor and TLV of a mixture see the appendix at the end of the CF table.

TLVs and Alarm Limits for Mixtures

The correction factor for mixtures can be used to set alarm limits for mixtures. To do this one first needs to calculate the exposure limit for the mixture. The Threshold Limit Value (TLV) often defines exposure limits. The TLV for the mixture is calculated in a manner similar to the CF calculation:

$$\text{TLV mix} = 1 / (X_1/\text{TLV}_1 + X_2/\text{TLV}_2 + X_3/\text{TLV}_3 + \dots X_i/\text{TLV}_i)$$

In the above example, the 8-h TLV for benzene is 0.5 ppm and for n-hexane 50 ppm. Therefore the TLV of the mixture is $\text{TLV}_{\text{mix}} = 1 / (0.05/0.5 + 0.95/50) = 8.4$ ppm, corresponding to 8.0 ppm hexane and 0.4 ppm benzene. For an instrument calibrated on isobutylene, the reading corresponding to the TLV is:

$$\text{Alarm Reading} = \text{TLV}_{\text{mix}} / \text{CF}_{\text{mix}} = 8.4 / 3.2 = 2.6 \text{ ppm}$$

A common practice is to set the lower alarm limit to half the TLV, and the higher limit to the TLV. Thus, one would set the alarms to 1.3 and 2.6 ppm, respectively.

Calibration Characteristics

a) Flow Configuration. PID response is essentially independent of gas flow rate as long as it is sufficient to satisfy the pump demand. Four main flow configurations are used for calibrating a PID:

- 1) Pressurized gas cylinder (Fixed-flow regulator):** The flow rate of the regulator should match the flow demand of the instrument pump or be slightly higher.
- 2) Pressurized gas cylinder (Demand-flow regulator):** A demand-flow regulator better matches pump speed differences, but results in a slight vacuum during calibration and thus slightly high readings.
- 3) Collapsible gas bag:** The instrument will draw the calibration gas from the bag at its normal flow rate, as long as the bag valve is large enough. The bag should be filled with enough gas to allow at least one minute of flow (~ 0.6 L for a MiniRAE, ~0.3 L for MultiRAE).

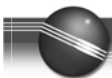
4) T (or open tube) method: The T method uses a T-junction with gas flow higher than the pump draw. The gas supply is connected to one end of the T, the instrument inlet is connected to a second end of the T, and excess gas flow escapes through the third, open end of the T. To prevent ambient air mixing, a long tube should be connected to the open end, or a high excess rate should be used. Alternatively, the instrument probe can be inserted into an open tube slightly wider than the probe. Excess gas flows out around the probe.

The first two cylinder methods are the most efficient in terms of gas usage, while the bag and T methods give slightly more accurate results because they match the pump flow better.

b) Pressure. Pressures deviating from atmospheric pressure affect the readings by altering gas concentration and pump characteristics. It is best to calibrate with the instrument and calibration gas at the same pressure as each other and the sample gas. (Note that the cylinder pressure is not relevant because the regulator reduces the pressure to ambient.) If the instrument is calibrated at atmospheric pressure in one of the flow configurations described above, then 1) pressures slightly above ambient are acceptable but high pressures can damage the pump and 2) samples under vacuum may give low readings if air leaks into the sample train.

c) Temperature. Because temperature effects gas density and concentration, the temperature of the calibration gas and instrument should be as close as possible to the ambient temperature where the unit will be used. We recommend that the temperature of the calibration gas be within the instrument's temperature specification (typically 14° to 113° F or -10° to 45° C). Also, during actual measurements, the instrument should be kept at the same or higher temperature than the sample temperature to avoid condensation in the unit.

d) Matrix. The matrix gas of the calibration compound and VOC sample is significant. Some common matrix components, such as methane and water vapor can affect the VOC signal. PIDs are



most commonly used for monitoring VOCs in air, in which case the preferred calibration gas matrix is air. For a MiniRAE, methane, methanol, and water vapor reduce the response by about 20% when their concentration is 15,000 ppm and by about 40% at 30,000 ppm. Despite earlier reports of oxygen effects, RAE PID responses with 10.6 eV lamps are independent of oxygen concentration, and calibration gases in a pure nitrogen matrix can be used. H₂ and CO₂ up to 5 volume % also have no effect.

- e) Concentration.** Although RAE Systems PIDs have electronically linearized output, it is best to calibrate in a concentration range close to the actual measurement range. For example, 100 ppm standard gas for anticipated vapors of 0 to 250 ppm, and 500 ppm standard for expected concentrations of 250 to 1000 ppm. The correction factors in this table were typically measured at 50 to 100 ppm and apply from the ppb range up to about 1000 ppm. Above 1000 ppm the CF may vary and it is best to calibrate with the gas of interest near the concentration of interest.
- f) Filters.** Filters affect flow and pressure conditions and therefore all filters to be used during sampling should also be in place during calibration. Using a water trap (hydrophobic filter) greatly reduces the chances of drawing water aerosols or dirt particles into the instrument. Regular filter replacements are recommended because dirty filters can adsorb VOCs and cause slower response time and shifts in calibration.
- g) Instrument Design.** High-boiling (“heavy”) or very reactive compounds can be lost by reaction or adsorption onto materials in the gas sample train, such as filters, pumps and other sensors. Multi-gas meters, including EntryRAE, MultiRAE and AreaRAE have the pump and other sensors upstream of the PID and are prone to these losses. Compounds possibly affected by such losses are shown in green in the table, and may give slow response, or in extreme cases, no response at all. In many cases the multi-gas meters can still give a rough indication of the relative concentration, without giving an accurate,

quantitative reading. The ppbRAE and MiniRAE series instruments have inert sample trains and therefore do not exhibit significant loss; nevertheless, response may be slow for the very heavy compounds and additional sampling time up to a minute or more should be allowed to get a stable reading.

Table Abbreviations:

CF = Correction Factor (multiply by reading to get corrected value for the compound when calibrated to isobutylene)

NR = No Response

IE = Ionization Energy (values in parentheses are not well established)

C = Confirmed Value indicated by “+” in this column; all others are preliminary or estimated values and are subject to change

ne = Not Established ACGIH 8-hr. TWA

C## = Ceiling value, given where 8-hr.TWA is not available

Disclaimer:

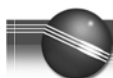
Actual readings may vary with age and cleanliness of lamp, relative humidity, and other factors. For accurate work, the instrument should be calibrated regularly under the operating conditions used. The factors in this table were measured in dry air at room temperature, typically at 50-100 ppm. CF values may vary above about 1000 ppm.

Updates:

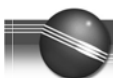
The values in this table are subject to change as more or better data become available. Watch for updates of this table on the Internet at

<http://www.raesystems.com>

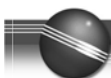
IE data are taken from the CRC Handbook of Chemistry and Physics, 73rd Edition, D.R. Lide (Ed.), CRC Press (1993) and NIST Standard Ref. Database 19A, NIST Positive Ion Energetics, Vers. 2.0, Lias, et.al., U.S. Dept. Commerce (1993). Exposure limits (8-h TWA and Ceiling Values) are from the 2005 ACGIH Guide to Occupational Exposure Values, ACGIH, Cincinnati, OH 2005. Equations for exposure limits for mixtures of chemicals were taken from the 1997 TLVs and BEIs handbook published by the ACGIH (1997).



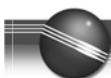
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C ₂ H ₄ O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	C ₂ H ₄ O ₂	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	C ₄ H ₆ O ₃	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C ₃ H ₆ O	1.2	+	1.1	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C ₄ H ₇ NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C ₂ H ₃ N					100		12.19	40
Acetylene	Ethyne	74-86-2	C ₂ H ₂					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C ₃ H ₄ O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	C ₃ H ₄ O ₂			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C ₃ H ₃ N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C ₃ H ₆ O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C ₃ H ₅ Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	H ₃ N	NR	+	9.7	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	C ₇ H ₁₄ O ₂	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	C ₅ H ₁₂ O			5		1.6		10.00	ne
Aniline	Aminobenzene	62-53-3	C ₇ H ₇ N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C ₇ H ₈ O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH ₃			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C ₇ H ₆ O					1		9.49	ne
Benzenamine, N-methyl-	N-Methylphenylamine	100-61-8	C ₇ H ₉ N			0.7				7.53	
Benzene		71-43-2	C ₆ H ₆	0.55	+	0.53	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C ₇ H ₅ N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C ₇ H ₈ O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C ₇ H ₇ Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	C ₈ H ₈ O ₂	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF ₃	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br ₂	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C ₆ H ₅ Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C ₃ H ₇ OBBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	CHBr ₃	NR	+	2.5	+	0.5	+	10.48	0.5
Bromopropane, 1-	n-Propyl bromide	106-94-5	C ₃ H ₇ Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C ₄ H ₆	0.8		0.85	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	C ₄ H ₆ O ₂	25	+	3.5	+	1.2		~10	ne
Butanal	1-Butanal	123-72-8	C ₄ H ₈ O			1.8				9.84	
Butane		106-97-8	C ₄ H ₁₀			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	C ₄ H ₁₀ O	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	C ₄ H ₁₀ O	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C ₄ H ₈			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	C ₆ H ₁₄ O ₂	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethanol acetate	Ethanol, 2-(2-butoxyethoxy)-, acetate	124-17-4	C ₁₀ H ₂₀ O ₄			5.6				≤10.6	
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol	112-34-5	C ₈ H ₁₈ O ₃			4.6				≤10.6	
Butyl acetate, n-		123-86-4	C ₆ H ₁₂ O ₂			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	C ₇ H ₁₂ O ₂			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	C ₄ H ₁₁ N	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve	see 2-Butoxyethanol	111-76-2									
Butyl hydroperoxide, t-		75-91-2	C ₄ H ₁₀ O ₂	2.0	+	1.6	+			<10	1
Butyl mercaptan	1-Butanethiol	109-79-5	C ₄ H ₁₀ S	0.55	+	0.52	+			9.14	0.5
Carbon disulfide		75-15-0	CS ₂	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl ₄	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve	see 2-Ethoxyethanol										
CFC-14	see Tetrafluoromethane										
CFC-113	see 1,1,2-Trichloro-1,2,2-trifluoroethane										



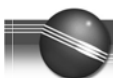
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Chlorine		7782-50-5	Cl ₂					1.0	+	11.48	0.5
Chlorine dioxide		10049-04-4	ClO ₂	NR	+	NR	+	NR	+	10.57	0.1
Chlorobenzene	Monochlorobenzene	108-90-7	C ₆ H ₅ Cl	0.44	+	0.40	+	0.39	+	9.06	10
Chlorobenzotrifluoride, 4-	PCBTf, OXSOL 100	98-56-6	C ₇ H ₄ ClF ₃	0.74	+	0.63	+	0.55	+	<9.6	25
	p-Chlorobenzotrifluoride										
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C ₄ H ₅ Cl			3					10
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	C ₂ H ₃ ClF ₂	NR		NR		NR		12.0	ne
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	CHClF ₂	NR		NR		NR		12.2	1000
Chloroethane	Ethyl chloride	75-00-3	C ₂ H ₅ Cl	NR	+	NR	+	1.1	+	10.97	100
Chloroethanol	Ethylene chlorhydrin	107-07-3	C ₂ H ₅ ClO					2.9		10.52	C1
Chloroethyl ether, 2-	bis(2-chloroethyl) ether	111-44-4	C ₄ H ₈ Cl ₂ O	8.6	+	3.0	+				5
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C ₃ H ₇ ClO			3					ne
Chloroform	Trichloromethane	67-66-3	CHCl ₃	NR	+	NR	+	3.5	+	11.37	10
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C ₄ H ₇ Cl	1.4	+	1.2	+	0.63	+	9.76	ne
Chloropicrin		76-06-2	CCl ₃ NO ₂	NR	+	~400	+	7	+	?	0.1
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C ₇ H ₇ Cl			0.5		0.6		8.83	50
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C ₇ H ₇ Cl					0.6		8.69	ne
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene	79-38-9	C ₂ ClF ₃	6.7	+	3.9	+	1.2	+	9.76	5
	Genetron 1113										
Chlorotrimethylsilane		75-77-4	C ₃ H ₉ ClSi	NR		NR		0.82	+	10.83	ne
Cresol, m-	m-Hydroxytoluene	108-39-4	C ₇ H ₈ O	0.57	+	0.50	+	0.57	+	8.29	5
Cresol, o-	o-Hydroxytoluene	95-48-7	C ₇ H ₈ O			1.0				8.50	
Cresol, p-	p-Hydroxytoluene	106-44-5	C ₇ H ₈ O			1.4				8.35	
Crotonaldehyde	trans-2-Butenal	123-73-9	C ₄ H ₆ O	1.5	+	1.1	+	1.0	+	9.73	2
		4170-30-3									
Cumene	Isopropylbenzene	98-82-8	C ₉ H ₁₂	0.58	+	0.54	+	0.4	+	8.73	50
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3
Cyclohexane		110-82-7	C ₆ H ₁₂	3.3	+	1.4	+	0.64	+	9.86	300
Cyclohexanol	Cyclohexyl alcohol	108-93-0	C ₆ H ₁₂ O	1.5	+	0.9	+	1.1	+	9.75	50
Cyclohexanone		108-94-1	C ₆ H ₁₀ O	1.0	+	0.9	+	0.7	+	9.14	25
Cyclohexene		110-83-8	C ₆ H ₁₀			0.8	+			8.95	300
Cyclohexylamine		108-91-8	C ₆ H ₁₃ N			1.2				8.62	10
Cyclopentane 85%		287-92-3	C ₅ H ₁₀	NR	+	15	+	1.1		10.33	600
2,2-dimethylbutane 15%											
Cyclopropylamine	Aminocyclopropane	765-30-0	C ₃ H ₇ N	1.1	+	0.9	+	0.9	+		ne
Decamethylcyclopentasiloxane		541-02-6	C ₁₀ H ₃₀ O ₅ Si ₅	0.16	+	0.13	+	0.12	+		ne
Decamethyltetrasiloxane		141-62-8	C ₁₀ H ₃₀ O ₃ Si ₄	0.17	+	0.13	+	0.12	+	<10.2	ne
Decane		124-18-5	C ₁₀ H ₂₂	4.0	+	1.4	+	0.35	+	9.65	ne
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	C ₆ H ₁₂ O ₂			0.7					50
Dibromochloromethane	Chlorodibromomethane	124-48-1	CHBr ₂ Cl	NR	+	5.3	+	0.7	+	10.59	ne
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	C ₃ H ₅ Br ₂ Cl	NR	+	1.7	+	0.43	+		0.001
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	C ₂ H ₄ Br ₂	NR	+	1.7	+	0.6	+	10.37	ne
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	C ₆ H ₄ Cl ₂	0.54	+	0.47	+	0.38	+	9.08	25
Dichlorodifluoromethane	CFC-12	75-71-8	CCl ₂ F ₂			NR	+	NR	+	11.75	1000
Dichlorodimethylsilane		75-78-5	C ₂ H ₆ Cl ₂ Si	NR		NR		1.1	+	>10.7	ne
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	C ₂ H ₄ Cl ₂			NR	+	0.6	+	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	C ₂ H ₂ Cl ₂			0.82	+	0.8	+	9.79	5
Dichloroethene, c-1,2-	c-1,2-DCE, cis-Dichloroethylene	156-59-2	C ₂ H ₂ Cl ₂			0.8				9.66	200
Dichloroethene, t-1,2-	t-1,2-DCE, trans-Dichloroethylene	156-60-5	C ₂ H ₂ Cl ₂			0.45	+	0.34	+	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	C ₂ H ₃ Cl ₂ F	NR	+	NR	+	2.0	+		ne
Dichloromethane	see Methylene chloride										



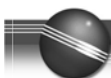
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C IE (eV)	TWA
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)	442-56-0 507-55-1	C ₃ HCl ₂ F ₅	NR	+	NR	+	25	+	ne
Dichloropropane, 1,2-		78-87-5	C ₃ H ₆ Cl ₂					0.7	10.87	75
Dichloro-1-propene, 1,3-		542-75-6	C ₃ H ₄ Cl ₂	1.3	+	0.96	+		<10	1
Dichloro-1-propene, 2,3-		78-88-6	C ₃ H ₄ Cl ₂	1.9	+	1.3	+	0.7	<10	ne
Dichloro-1,1,1-trifluoroethane, 2,2-	R-123	306-83-2	C ₂ HCl ₂ F ₃	NR	+	NR	+	10.1	+	11.5
Dichloro-2,4,6-trifluoropyridine, 3,5-	DCTFP	1737-93-5	C ₅ Cl ₂ F ₃ N	1.1	+	0.9	+	0.8	+	ne
Dichlorvos *	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	C ₄ H ₇ Cl ₂ O ₄ P			0.9	+		<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	C ₁₀ H ₁₂	0.57	+	0.48	+	0.43	+	8.8
Diesel Fuel		68334-30-5	m.w. 226			0.9	+			11
Diesel Fuel #2 (Automotive)		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+	11
Diethylamine		109-89-7	C ₄ H ₁₁ N			1	+		8.01	5
Diethylaminopropylamine, 3-		104-78-9	C ₇ H ₁₈ N ₂			1.3				ne
Diethylbenzene	See Dowtherm J									
Diethylmaleate		141-05-9	C ₈ H ₁₂ O ₄			4				ne
Diethyl sulfide	see Ethyl sulfide									
Diglyme	See Methoxyethyl ether	111-96-6	C ₆ H ₁₄ O ₃							
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	C ₉ H ₁₈ O	0.71	+	0.61	+	0.35	+	9.04
Diisopropylamine		108-18-9	C ₆ H ₁₅ N	0.84	+	0.74	+	0.5	+	7.73
Diketene	Ketene dimer	674-82-8	C ₄ H ₄ O ₂	2.6	+	2.0	+	1.4	+	9.6
Dimethylacetamide, N,N-	DMA	127-19-5	C ₄ H ₉ NO	0.87	+	0.8	+	0.8	+	8.81
Dimethylamine		124-40-3	C ₂ H ₇ N			1.5			8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	C ₃ H ₆ O ₃	NR	+	~70	+	1.7	+	~10.5
Dimethyl disulfide	DMDS	624-92-0	C ₂ H ₆ S ₂	0.2	+	0.20	+	0.21	+	7.4
Dimethyl ether	see Methyl ether									
Dimethylethylamine	DMEA	598-56-1	C ₄ H ₁₁ N	1.1	+	1.0	+	0.9	+	7.74
Dimethylformamide, N,N-	DMF	68-12-2	C ₃ H ₇ NO	0.7	+	0.7	+	0.8	+	9.13
Dimethylhydrazine, 1,1-	UDMH	57-14-7	C ₂ H ₈ N ₂			0.8	+	0.8	+	7.28
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	C ₃ H ₉ O ₃ P	NR	+	4.3	+	0.74	+	10.0
Dimethyl sulfate		77-78-1	C ₂ H ₆ O ₄ S	~23		~20	+	2.3	+	0.1
Dimethyl sulfide	see Methyl sulfide									
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C ₂ H ₆ OS			1.4	+		9.10	ne
Dioxane, 1,4-		123-91-1	C ₄ H ₈ O ₂			1.3			9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	C ₃ H ₆ O ₂	4.0	+	2.3	+	1.6	+	9.9
Dowtherm A see Therminol® *										
Dowtherm J (97% Diethylbenzene) *		25340-17-4	C ₁₀ H ₁₄			0.5				
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+	ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro2,3-epoxypropane	106-89-8	C ₂ H ₅ ClO	~200	+	8.5	+	1.4	+	10.2
Ethane		74-84-0	C ₂ H ₆			NR	+	15	+	11.52
Ethanol	Ethyl alcohol	64-17-5	C ₂ H ₆ O			10	+	3.1	+	10.47
Ethanolamine *	MEA, Monoethanolamine	141-43-5	C ₂ H ₇ NO	5.6	+	1.6	+		8.96	3
Ethene	Ethylene	74-85-1	C ₂ H ₄			9	+	4.5	+	10.51
Ethoxyethanol, 2-	Ethyl cellosolve	110-80-5	C ₄ H ₁₀ O ₂			1.3			9.6	5
Ethyl acetate		141-78-6	C ₄ H ₈ O ₂			4.6	+	3.5	10.01	400
Ethyl acetoacetate		141-97-9	C ₆ H ₁₀ O ₃	1.4	+	1.2	+	1.0	<10	ne
Ethyl acrylate		140-88-5	C ₅ H ₈ O ₂			2.4	+	1.0	<10.3	5
Ethylamine		75-04-7	C ₂ H ₇ N			0.8			8.86	5



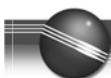
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C IE (Ev)	TWA
Ethylbenzene		100-41-4	C ₈ H ₁₀	0.52	+	0.52	+	0.51	+	8.77 100
Ethyl caprylate	Ethyl octanoate	106-32-1	C ₁₀ H ₂₀ O ₂		+	0.52	+	0.51	+	
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	C ₂ H ₈ N ₂	0.9	+	0.8	+	1.0	+	8.6 10
Ethylene glycol *	1,2-Ethandiol	107-21-1	C ₂ H ₆ O ₂			16	+	6	+	10.16 C100
Ethylene glycol, Acrylate	2-hydroxyethyl Acrylate	818-61-1	C ₅ H ₈ O ₃			8.2				≤10.6
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	C ₄ H ₁₀ O ₂	1.1		0.86		0.7		9.2 ne
Ethylene glycol monobutyl ether acetate	2-Butoxyethyl acetate	112-07-2	C ₈ H ₁₆ O ₃			1.3				≤10.6
Ethylene glycol, monothio	mercapto-2-ethanol	60-24-2	C ₂ H ₆ OS			1.5				9.65
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C ₂ H ₄ O			13	+	3.5	+	10.57 1
Ethyl ether	Diethyl ether	60-29-7	C ₄ H ₁₀ O			1.1	+	1.7		9.51 400
Ethyl 3-ethoxypropionate	EEP	763-69-9	C ₇ H ₁₄ O ₃	1.2	+	0.75	+			ne
Ethyl formate		109-94-4	C ₃ H ₆ O ₂					1.9		10.61 100
Ethylhexyl □acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	C ₁₁ H ₂₀ O ₂			1.1	+	0.5	+	ne
Ethylhexanol	2-Ethyl-1-hexanol	104-76-7	C ₈ H ₁₈ O			1.9				≤10.6
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1)hept-2-ene	16219-75-3	C ₉ H ₁₂	0.4	+	0.39	+	0.34	+	≤8.8 ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	C ₅ H ₁₀ O ₃	13	+	3.2	+	1.6	+	~10 ne
Ethyl mercaptan	Ethanethiol	75-08-1	C ₂ H ₆ S	0.60	+	0.56	+			9.29 0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	C ₄ H ₁₀ S			0.5	+			8.43 ne
Formaldehyde	Formalin	50-00-0	CH ₂ O	NR	+	NR	+	1.6	+	10.87 C0.3
Formamide		75-12-7	CH ₃ NO			6.9	+	4		10.16 10
Formic acid		64-18-6	CH ₂ O ₂	NR	+	NR	+	9	+	11.33 5
Furfural	2-Furaldehyde	98-01-1	C ₅ H ₄ O ₂			0.92	+	0.8	+	9.21 2
Furfuryl alcohol		98-00-0	C ₅ H ₆ O ₂			0.80	+			<9.5 10
Gasoline #1		8006-61-9	m.w. 72			0.9	+			300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+	300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	C ₅ H ₈ O ₂	1.1	+	0.8	+	0.6	+	C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	C ₇ H ₁₀ O ₃	2.6	+	1.2	+	0.9	+	0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	C ₂ HBrClF ₃					0.6		11.0 50
HCFC-22 see Chlorodifluoromethane HCFC-123 see 2,2-Dichloro-1,1,1-trifluoroethane HCFC-141B see 1,1-Dichloro-1-fluoroethane HCFC-142B see 1-Chloro-1,1-difluoroethane HCFC-134A see 1,1,1,2-Tetrafluoroethane HCFC-225 see Dichloropentafluoropropane										
Heptane, n-		142-82-5	C ₇ H ₁₆	45	+	2.8	+	0.60	+	9.92 400
Heptanol, 4-	Dipropylcarbinol	589-55-9	C ₇ H ₁₆ O	1.8	+	1.3	+	0.5	+	9.61 ne
Hexamethyldisilazane, 1,1,1,3,3,3- *	HMDS	999-97-3	C ₆ H ₁₉ NSi ₂			0.2	+	0.2	+	~8.6 ne
Hexamethyldisiloxane	HMDSx	107-46-0	C ₆ H ₁₈ OSi ₂	0.33	+	0.27	+	0.25	+	9.64 ne
Hexane, n-		110-54-3	C ₆ H ₁₄	350	+	4.3	+	0.54	+	10.13 50
Hexanol, 1-	Hexyl alcohol	111-27-3	C ₆ H ₁₄ O	9	+	2.5	+	0.55	+	9.89 ne
Hexene, 1-		592-41-6	C ₆ H ₁₂			0.8				9.44 30
HFE-7100	see Methyl nonafluorobutyl ether									
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+	ne
Hydrazine *		302-01-2	H ₄ N ₂	>8	+	2.6	+	2.1	+	8.1 0.01
Hydrazoic acid	Hydrogen azide		HN ₃							10.7
Hydrogen	Synthesis gas	1333-74-0	H ₂	NR	+	NR	+	NR	+	15.43 ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+	13.6 C4.7
Hydrogen iodide *	Hydriodic acid	10034-85-2	HI			~0.6*				10.39
Hydrogen peroxide		7722-84-1	H ₂ O ₂	NR	+	NR	+	NR	+	10.54 1
Hydrogen sulfide		7783-06-4	H ₂ S	NR	+	3.3	+	1.5	+	10.45 10
Hydroxypropyl methacrylate		27813-02-1	C ₇ H ₁₂ O ₃	9.9	+	2.3	+	1.1	+	ne
		923-26-2								
Iodine *		7553-56-2	I ₂	0.1	+	0.1	+	0.1	+	9.40 C0.1



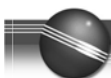
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Iodomethane	Methyl iodide	74-88-4	CH ₃ I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	C ₇ H ₁₄ O ₂	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C ₄ H ₁₀			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	C ₄ H ₁₀ O	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C ₄ H ₈	1.00	+	1.00	+	1.00	+	9.24	Ne
Isobutyl acrylate	Isobutyl 2-propenoate	106-63-8	C ₇ H ₁₂ O ₂			1.5	+	0.60	+		Ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	C ₃ H ₂ ClF ₅ O	NR	+	NR	+	48	+	~11.7	Ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C ₈ H ₁₈			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				Ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				Ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		Ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		Ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		Ne
Isopentane	2-Methylbutane	78-78-4	C ₅ H ₁₂			8.2					Ne
Isophorone		78-59-1	C ₉ H ₁₄ O					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C ₅ H ₈	0.69	+	0.63	+	0.60	+	8.85	Ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C ₃ H ₈ O	500	+	6.0	+	2.7		10.12	200
Isopropyl acetate		108-21-4	C ₅ H ₁₀ O ₂			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	C ₆ H ₁₄ O			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40	8008-20-6 +	m.w. 115			1.0	+	0.4	+		Ne
	Wide cut type aviation fuel	64741-42-0									
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 +	m.w. 167			0.6	+	0.5	+		29
		64747-77-1									
Jet fuel JP-8	Jet A-1, F-34, Kerosene type aviation fuel	8008-20-6 +	m.w. 165			0.6	+	0.3	+		30
		64741-77-1									
Jet fuel A-1 (JP-8)	F-34, Kerosene type aviation fuel	8008-20-6 +	m.w. 145			0.67					34
		64741-77-1									
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel	8008-20-6 +	m.w. 165	0.9	+	0.6	+	0.3	+		30
		64742-47-8									
Limonene, D-	(R)-(+)-Limonene	5989-27-5	C ₁₀ H ₁₆			0.33	+			~8.2	Ne
Kerosene C10-C16 petro.distillate – see Jet Fuels		8008-20-6									
MDI – see 4,4'-Methylenebis(phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	C ₄ H ₂ O ₃							~10.8	0.1
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C ₉ H ₁₂	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride – see 3-Chloro-2-methylpropene											
Methane	Natural gas	74-82-8	CH ₄	NR	+	NR	+	NR	+	12.61	Ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH ₄ O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	C ₃ H ₈ O ₂	4.8	+	2.4	+	1.4	+	10.1	5
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol	111-77-3	C ₇ H ₁₆ O	2.3	+	1.2	+	0.9	+	<10	Ne
	Diethylene glycol monomethyl ether										
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	C ₆ H ₁₄ O ₃	0.64	+	0.54	+	0.44	+	<9.8	Ne
Methyl acetate		79-20-9	C ₃ H ₆ O ₂	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	C ₄ H ₆ O ₂			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH ₅ N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	C ₇ H ₁₄ O	0.9	+	0.85	+	0.5	+	9.30	50
Methyl bromide	Bromomethane	74-83-9	CH ₃ Br	110	+	1.7	+	1.3	+	10.54	1
Methyl t-butyl ether	MTBE, <i>tert</i> -Butyl methyl ether	1634-04-4	C ₅ H ₁₂ O			0.9	+			9.24	40
Methyl cellosolve	see 2-Methoxyethanol										
Methyl chloride	Chloromethane	74-87-3	CH ₃ Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C ₇ H ₁₄	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis(phenylisocyanate), 4,4'- *	MDI, Mondur M		C ₁₅ H ₁₀ N ₂ O ₂							Very slow ppb level response	0.005



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methylene chloride	Dichloromethane	75-09-2	CH ₂ Cl ₂	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C ₂ H ₆ O	4.8	+	3.1	+	2.5	+	10.03	Ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C ₄ H ₈ O	0.86	+	0.9	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	C ₂ H ₆ N ₂	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAC, 5-Methyl-2-hexanone	110-12-3	C ₇ H ₁₄ O	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	C ₆ H ₁₂ O	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate	CH ₃ NCO	624-83-9	C ₂ H ₃ NO	NR	+	4.6	+	1.5		10.67	0.02
Methyl isothiocyanate	CH ₃ NCS	551-61-6	C ₂ H ₃ NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH ₄ S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	C ₅ H ₈ O ₂	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	C ₅ H ₃ F ₉ O			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2-(coats lamp) *	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	C ₆ H ₁₆ N ₂			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	C ₅ H ₁₂ O			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C ₅ H ₉ NO	1.0	+	0.8	+	0.9	+	9.17	ne
Methyl salicylate	Methyl 2-hydroxybenzoate	119-36-8	C ₈ H ₈ O ₃	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C ₉ H ₁₀			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C ₂ H ₆ S	0.49	+	0.44	+	0.46	+	8.69	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5, 8052-41-3, 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits - Viscor 120B Calibration Fluid, b.p. 156-207°C		8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100
Monoethanolamine - see Ethanolamine											
Mustard *	HD, Bis(2-chloroethyl) sulfide	505-60-2, 39472-40-7, 68157-62-0	C ₄ H ₈ Cl ₂ S			0.6					0.0005
Naphtha - see VM & P Naptha											
Naphthalene	Mothballs	91-20-3	C ₁₀ H ₈	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C ₄ NiO ₄			0.18				<8.8	0.001
Nicotine		54-11-5	C ₁₀ H ₁₄ N ₂			2.0				≤10.6	
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	C ₆ H ₅ NO ₂	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	C ₂ H ₅ NO ₂					3		10.88	100
Nitrogen dioxide		10102-44-0	NO ₂	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF ₃	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH ₃ NO ₂					4		11.02	20
Nitropropane, 2-		79-46-9	C ₃ H ₇ NO ₂					2.6		10.71	10
Nonane		111-84-2	C ₉ H ₂₀			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C ₁₀ -C ₁₃	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C ₁₃ -C ₁₄	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	C ₈ H ₂₄ O ₄ Si ₄	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	C ₈ H ₂₄ O ₂ Si ₃	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C ₈ H ₁₈	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C ₈ H ₁₆	0.9	+	0.75	+	0.4	+	9.43	75
Pentane		109-66-0	C ₅ H ₁₂	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix *	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	C ₂ H ₄ O ₃			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C ₂ Cl ₄	0.69	+	0.57	+	0.31	+	9.32	25
PGME	Propylene glycol methyl ether, 1-Methoxy-2-propanol	107-98-2	C ₆ H ₁₂ O ₃	2.4	+	1.5	+	1.1	+		100



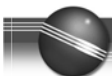
Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
PGMEA	Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	108-65-6	C ₆ H ₁₂ O ₃	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C ₆ H ₆ O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl ₂ O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH ₃	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C ₆ H ₇ N			0.9				9.04	ne
Pinene, α-		2437-95-8	C ₁₀ H ₁₆			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	C ₁₀ H ₁₆	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C ₅ H ₈	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C ₃ H ₈			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C ₃ H ₈ O			5		1.7		10.22	200
Propene	Propylene	115-07-1	C ₃ H ₆	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C ₃ H ₆ O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	C ₅ H ₁₀ O ₂			3.5		2.3		10.04	200
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C ₃ H ₉ N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate *		108-32-7	C ₄ H ₆ O ₃			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	C ₃ H ₈ O ₂	18		5.5	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	C ₆ H ₁₄ O ₂	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9	C ₃ H ₆ O	~240		6.6	+	2.9	+	10.22	20
		16088-62-3									
		15448-47-2									
Propyleneimine	2-Methylaziridine	75-55-8	C ₃ H ₇ N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C ₃ H ₈ S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C ₅ H ₅ N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C ₄ H ₉ N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol:1-Methoxy-2-acetoxypropane)	107-98-2	C ₄ H ₁₀ O ₂ / C ₆ H ₁₂ O ₃			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8	C ₄ H ₁₀ FO ₂ P			~3					
		50642-23-4									
Stoddard Solvent - see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C ₈ H ₈	0.45	+	0.40	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO ₂	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF ₆	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO ₂ F ₂	NR		NR		NR		13.0	5
Tabun *	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	C ₅ H ₁₁ N ₂ O ₂ P			0.8					15ppt
Tetrachloroethane, 1,1,1,2-		630-20-6	C ₂ H ₂ Cl ₄					1.3		~11.1	ne
Tetrachloroethane, 1,1,1,2-		79-34-5	C ₂ H ₂ Cl ₄	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	SiCl ₄	NR		NR		15	+	11.79	ne
Tetraethyl lead	TEL	78-00-2	C ₈ H ₂₀ Pb	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	C ₈ H ₂₀ O ₄ Si			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	C ₂ H ₂ F ₄			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C ₂ F ₄			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF ₄			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C ₄ H ₈ O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	C ₄ H ₁₂ O ₄ Si	10	+	1.9	+			~10	1
Therminol® D-12 *	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1 *	Dowtherm A, 3:1 Diphenyl oxide: Biphenyl	101-84-8	C ₁₂ H ₁₀ O			0.4	+				1
		92-52-4	C ₁₂ H ₁₀								
Toluene	Methylbenzene	108-88-3	C ₇ H ₈	0.54	+	0.50	+	0.51	+	8.82	50



Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	C ₉ H ₆ N ₂ O ₂	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	C ₆ H ₃ Cl ₃	0.7	+	0.46	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	C ₂ H ₃ Cl ₃			NR	+	1	+	11	350
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	C ₂ H ₃ Cl ₃	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichloroethylene	79-01-6	C ₂ HCl ₃	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH ₃ Cl ₃ Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	C ₂ Cl ₃ F ₃			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	C ₆ H ₁₅ N	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester	150-46-9	C ₆ H ₁₅ O ₃ B			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	C ₆ H ₁₅ O ₄ P	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	C ₂ H ₃ F ₃					34		12.9	ne
Trimethylamine		75-50-3	C ₃ H ₉ N			0.9				7.82	5
Trimethylbenzene, 1,3,5- - see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	C ₃ H ₉ O ₃ B			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	C ₃ H ₉ O ₄ P			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	C ₃ H ₉ O ₃ P			1.1	+		+	8.5	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	C ₁₀ H ₁₆	0.37	+	0.30	+	0.29	+	~8	20
Undecane		1120-21-4	C ₁₁ H ₂₄			2				9.56	ne
Varsol – see Mineral Spirits											
Vinyl acetate		108-05-4	C ₄ H ₆ O ₂	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C ₂ H ₃ Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C ₂ H ₃ Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C ₈ H ₁₂	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride - see 1,1-Dichloroethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C ₆ H ₉ NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B - see Mineral Spirits - Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naphtha	64742-89-8	m.w. 111 (C ₈ -C ₉)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C ₈ H ₁₀	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C ₈ H ₁₀	0.56	+	0.46	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C ₈ H ₁₀	0.48	+	0.39	+	0.38	+	8.44	100
None				1		1		1			
Undetectable				1E+6		1E+6		1E+6			

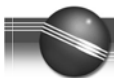
* Compounds indicated in green can be detected using a MiniRAE 2000 or ppbRAE/+ with slow response, but may be lost by adsorption on a MultiRAE or EntryRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

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**Appendix I:****Example of Automatic Calculation of Correction Factors, TLVs and Alarm Limits for Mixtures**

(Calculations performed using Excel version of this database, available on request)

Compound	CF 9.8 eV	CF 10.6 eV	CF 11.7eV	Mol. Frac	Conc ppm	TLV ppm	STEL Ppm
Benzene	0.55	0.53	0.6	0.01	1	0.5	2.5
Toluene	0.54	0.5	0.51	0.06	10	50	150
Hexane, n-	300	4.3	0.54	0.06	10	50	150
Heptane, n-	45	2.8	0.6	0.28	50	400	500
Styrene	0.45	0.4	0.42	0.06	10	20	40
Acetone	1.2	1.1	1.4	0.28	50	750	1000
Isopropanol	500	6	2.7	0.28	50	400	500
None	1	1	1	0.00	0	1	
Mixture Value:	2.1	1.5	0.89	1.00	181	56	172
TLV Alarm Setpoint when Calibrated to Isobutylene:	26 ppm	37 ppm	62 ppm		ppm	ppm	ppm
STEL Alarm Setpoint, same Calibration	86 ppm	115 ppm	193 ppm				



Correction Factors for Combustible Gas (LEL) Sensors

LEL Correction Factors

RAE Systems LEL sensors (including LEL-only sensor and LEL/TC dual-range sensor) can be used for the detection of a wide variety of combustible gases and vapors that exhibit different responses. Because LEL sensors use a diffusion barrier to limit the gas flux to the catalytic bead, they tend to have the greatest sensitivity to high-diffusivity compounds. Therefore, they are substantially more sensitive to small molecules like hydrogen and methane than to heavy components like kerosene. The best way to calibrate any sensor to different compounds is to use a standard of the gas of interest. However, Correction Factors (CFs) have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically methane or pentane. In our LEL sensors, Correction Factors can be used in one of three ways:

1. Calibrate the unit with methane in the usual fashion to read in methane %LEL equivalents. Manually multiply the reading by the Correction Factor (CF) to obtain the %LEL of the gas being measured.
2. Calibrate the unit with methane and then call up the Correction Factor from the instrument memory. The unit then reads directly in %LEL of the gas of interest.
3. Calibrate the unit with methane, but input an equivalent, "corrected" span gas concentration when prompted for this value. For example, to read in isopropanol LEL units, apply 20% LEL methane but enter $20 \times 2.6 = 52$ for the span gas concentration.

Oxygen Requirement and Matrix Effects

LEL sensors require oxygen for combustion and cannot be used in environments that contain less than 10 vol% oxygen. This threshold is the safe limit for up to 100% LEL of nearly all chemicals, but it depends on the combustible gas concentration. For example, for 10% LEL methane, RAE Systems LEL sensors show little or no oxygen dependence down to about 5 vol% oxygen. Inserting an LEL sensor from

air into pure nitrogen can cause a transient response that decays after several minutes to the background reading. This is because the reference bead takes time to equilibrate with the slightly lower thermal conductivity of the nitrogen. Likewise, other inert matrix gases may cause a transient response.

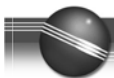
Humidity and temperature generally have little effect on the sensor response. Increasing temperature increases the response by less than 6% between 0° and 40° C. Increasing RH (relative humidity) decreases the response by 8% between 5% and 95% RH. Some LEL sensor-instrument combinations have a small humidity response and may read a few % LEL in air at 50% RH if zeroed with dry air.

Methane Sensitivity Changes

The Correction Factors in this table apply to new sensors. As a sensor becomes used and gradually loses sensitivity, the response to methane may decrease more rapidly than for higher hydrocarbons. In this case, the Correction Factors gradually decrease, and calibration with methane tends to overestimate the %LEL of the other gas. Therefore, methane calibration is the safest approach. RAE Systems LEL sensors do not exhibit changes in Correction Factors in laboratory tests, but may do so under special-use conditions. Calibrating with other organic vapors such as propane or pentane is a good way to avoid Correction Factor changes. The only drawback to this approach is that it is possible to miss methane while still measuring the higher hydrocarbons. If methane is known to be absent under all circumstances, the use of propane or pentane calibration is appropriate.

Correction Factors when Calibrating with Non-methane Compounds

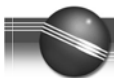
To obtain Correction Factors for other span gases, simply divide the value on the methane scale in the table by the methane value for the span compound. For example, to obtain CFs on the n-pentane scale, divide all the numbers in the table by 2.2. Thus, when calibrating with n-pentane the new CF for acetylene is $2.8/2.2 = 1.3$, and the new CF for ammonia is $0.8/2.2 = 0.4$. Note that this calculation is done internally in RAE Systems instruments that have separately selectable span and measurement gases.



Therefore, in these cases, simply enter the span and measurement compounds (without changing the CFs), and the unit automatically calculates and applies the new factor.

Chemical	100% LEL (Vol%)	LEL CF*
Acetaldehyde	4.0	1.8
Acetic acid	4.0	3.4
Acetic Anhydride	2.7	2.0
Acetone	2.5	2.2
Acetylene	2.5	2.8
Allyl Alcohol	2.5	1.7
Ammonia	15.0	0.8
Aniline	1.3	3.0
Benzene	1.2	2.2
Butadiene, 1,3-	2.0	2.5
Butane, n-	1.9	2.0
Butane, i-	1.8	1.8
Butanol, n-	1.4	3.0
Butanol, i-	1.7	2.5
Butanol, t-	2.4	1.8
Butene-1	1.6	2.1
Butene-2, cis	1.7	2.1
Butene-2, trans	1.8	1.9
Butyric acid	2.0	2.4
Carbon disulfide	1.3	**
Carbon monoxide	12.5	1.2
Carbonyl sulfide	12.0	1.0
Chlorobenzene	1.3	3.0
Chloropropane, 1-	2.6	1.8
Cyanogen	6.6	1.1
Cyclohexane	1.3	2.5
Cyclopropane	2.4	1.5
Decane, n-	0.8	3.4
Dichloroethane, 1,2-	6.2	1.5
Dichloromethane	13.0	1.0
Dimethylbutane	1.2	2.7
Dimethylpentane, 2,3-	1.1	2.3
Dimethyl sulfide	2.2	2.3
Dioxane, 1,4-	2.0	2.5
Ethane	3.0	1.4
Ethanol	3.3	1.7
Ethene	2.7	1.4
Ethyl acetate	2.0	2.2
Ethylamine	3.5	1.4
Ethyl benzene	0.8	2.8
Ethyl bromide	6.8	0.9
Ethyl chloride	3.8	1.7
Ethyl ether	1.9	2.3
Ethyl formate	2.8	2.4

Chemical	100% LEL (Vol%)	LEL CF*
Ethyl mercaptan	2.8	1.8
Ethyl methyl ether	2.0	2.3
Ethyl pentane	1.2	2.4
Ethylene oxide	3.0	2.3
Gasoline,	1.3	2.1
Heptane, n-	1.1	2.4
Hexadiene, 1,4-	2.0	1.5
Hexane, n-	1.1	2.3
Hydrazine	2.9	2.1
Hydrogen	4.0	1.1
Hydrogen cyanide	5.6	2.0
Hydrogen sulfide	4.0	**
Isobutene (Isobutylene)	1.8	1.5
Isopropanol	2.0	2.6
Jet fuel JP-4, -5, -8	0.6***	***
Methane	5.0	1.0
Methanol	6.0	1.5
Methyl acetate	3.1	2.2
Methylamine	4.9	1.3
Methyl bromide	10.0	1.1
Methyl chloride	8.1	1.3
Methylcyclohexane	1.2	2.6
Methyl ether	3.4	1.7
Methyl ethyl ketone	1.4	2.6
Methyl formate	4.5	1.9
Methyl hexane	1.2	2.4
Methyl mercaptan	3.9	1.6
Methylpentane	1.2	2.7
Methyl propionate	2.5	2.1
Methyl n-propyl ketone (2-pentanone)	1.5	2.7
Naphthalene	0.9	2.9
Nitromethane	7.3	2.1
Nonane, n-	0.8	3.2
Octane, n-	1.0	2.9
Pentane, n-	1.5	2.2
Pentane, i-	1.4	2.3
Pentane, Neo-	1.4	2.5
Pentene, 1-	1.5	2.3
Phosphine	1.6	0.3
Propane	2.1	1.6
Propanol, n-	2.2	2.0
Propene	2.0	1.5
Pentane, n-	1.5	2.2
Pentane, i-	1.4	2.3
Pentane, Neo-	1.4	2.5
Pentene, 1-	1.5	2.3
Phosphine	1.6	0.3



Chemical	100% LEL (Vol%)	LEL CF*
Propane	2.1	1.6
Propanol, n-	2.2	2.0
Propene	2.0	1.5
Propylamine, n-	2.0	2.1
Propylene oxide	2.3	2.6
Propyl ether, iso-	1.4	2.3
Propyne	1.7	2.3
Toluene	1.1	2.6
Triethylamine	1.2	2.5
Trimethylamine	2.0	1.9
Trimethylbutane	1.2	2.3
Turpentine	0.8	2.9
Vinyl chloride	3.6	1.8
Xylene, m-	1.1	2.7
Xylene, o-	0.9	3.0
Xylene, p-	1.1	2.8

* Values in italics are calculated from diffusion properties; values in normal type are confirmed with RAE Systems sensors.

**** Caution!** On LEL/TC sensors (3R/TC & 4R/TC) CS₂ may cause a large baseline shift and sensitivity loss; for LEL-only sensors (4R), an approximate CF of 3±2 can be used. H₂S may cause a large baseline shift and sensitivity loss on LEL and TC/LEL sensors. Therefore, attempts to measure the LEL of H₂S should be made as quickly as possible and may not be reliable.

******* Reported values of the lower explosive limit for jet fuels range from about 0.3% to 0.9% by volume. An earlier third-party test reported a CF for jet fuels of 3.35. However, we have been unable to confirm this result and recommend using a PID as a much more accurate method of measuring LEL for jet and diesel fuels.